The following publication Niu, B., Chen, L., Liu, Y., & Jin, Y. (2019). Joint price and quality decisions considering Chinese customers' variety seeking behavior. International Journal of Production Economics, 213, 97-107 is available at https://doi.org/10.1016/j.ijpe.2019.02.022

Joint price and quality decisions considering Chinese customers’ variety seeking behavior

Abstract

Variety seeking behavior indicates that customers get boredom of the products they purchased before, and prefer new products when they want to purchase again. Considering this, firms have to adjust their price and quality decisions to keep “old” and find “new” customers. In this paper, we build a two-period stylized model by assuming firms’ cost is effort-dependent, which characterizes the tradeoff between managing variety seeking customers and the cost of quality improvement. We show that, customers’ variety seeking behavior leads to a mild competition in period 1 but a fierce competition in period 2, and the existence of variety seeking customers reduces firms’ incentives to improve the quality levels. Regarding price decision, we find that firms charge a low retail price in period 2, but in period 1 the price depends on the effort cost coefficient. Interestingly, we find that firms may be worse off in a mixed market of both regular and variety seeking customers, when the effort cost coefficient is small. That is, firms’ highly efficient quality improvement can be harmful when customers are variety seeking.

Keywords: variety seeking behavior; two-period model; quality improvement; pricing

1 Introduction

Variety seeking behavior, by definition, is customers' behavior that they get boredom of the purchased products and will be more willing to choose products that have not been bought before (Bass et al. 1972). This behavior is widely observed, especially in today's China, because in the recent decades more and more new products are emerging and more and more China customers are interested in dynamic lifestyles (China Daily 2017). They like to "*try new things and buy products that may be new to them*" (Nielsen 2018). For example, in automobile industry, it is easy to find products from Great Wall, Geely, BYD and Chery, which are attracting many customers who might have bought traditional automobiles from Toyota, Honda and Ford (McKinsey China, 2015).

Chinese customers' variety seeking behavior is also investigated by empirical literature. For example, Grünhagen et al. (2012) point out that, as more and more foreign products and brands gain access to the Chinese market, Chinese customers show their desires for the new things. In the product classes suchlike food and fashion brands, variety seeking customers are widely observed (Simonson, 1990). Che et al. (2007) indicate that, the extent of variety seeking customers in fast food industry is around 27%. Kim and Markus (1999) attribute Chinese customers' variety seeking behavior to their culture. They point out that, compared to the individualistic Western customers, Chinese customers prefer following the mainstream, which would be frequently changing.

Nowadays, Chinese market and Chinese customers have played more and more significant roles in global trade. A recent report by McKinsey indicates that, the sales on the so-called Singles Day in China are larger than the sum of that on the Black Friday and Cyber Monday in the United States (McKinsey, 2017). Apple Inc. also points out the key role of Chinese market. Its 2018 second quarter report reveals that, the revenue growth rate in Chinese market exceeded 20% (Apple News, 2018).

Therefore, for brand-owners, Chinese market could not be ignored and Chinese customers' variety seeking behavior might significantly influence their profit gains in Chinese market. How to manage variety seeking customers? Previous literature such as Seetharaman and Che (2009) suggests the pricing weapon: Usually, there are at least two purchasing periods, where the variety seeking customers will buy one product in period 1 but buy an alternative product in period 2. A firm can lower the price in period 2 to snatch more regular customers who are not affected by the previous purchasing behavior, wait for the rival's variety seeking customers and give up part of its own variety seeking customers. Having said that, pricing it own is not powerful enough. Based on a survey by J.D. Power and Associates, price and quality are the two most important items that can attract customers (Chao et al. 2009). Some other surveys in software industry even show that quality is the most important item for customers' purchasing decisions (Zhang and Niu 2014, Sheetal and Harsh 2002). Therefore, a natural research question arises: Will it be more effective to manage variety seeking customers in a joint price and quality decision-making model? Will the involvement of quality decision improve or hurt firm's profitability? In practice, more and more firms have emphasized the role of quality decision (McKinsey, 2015). For example, McKinsey's "2017 China Consumer Report" says that, Xiaomi and Huawei, two famous China smart phone manufacturers, have made continuous efforts to adjust the price and quality levels to survive in a market full of variety seeking customers (McKinsey, 2017), especially when they sell goods via online and media platforms (Nielsen 2018).

Therefore, in this paper, we build a two-period stylized model to study two competing firms' joint price and quality decisions in the presence of variety seeking customers. We use the Hotelling framework to formulate customers' choice behavior and variety seeking behavior. Before the selling season, firms decide their quality levels and prices sequentially. We consider three market structures: (1) a market full of regular customers. (2) a mixed market of regular and variety seeking customers; (3) a market full of variety seeking customers. *Structure (1) and (3) are benchmark cases that show the properties of Structure (2) – the mixed structure which is widely observed in practice*.

We first study firms' competition and find that, the existence of variety seeking customers can mitigate the competition in period 1, whereas the opposite is true in period 2. That is, firms will compete more fiercely in period 2 to guarantee their profit gains.

We then focus on firms' price and quality decisions. We find that, the existence of variety seeking customers weakens firms' incentives to improve the quality levels. The intuition is clear: as part of variety seeking customers will definitely go to the rival in period 2, why do firms invest in quality improvement to keep them? In addition, as part of rival's variety seeking customers will definitely come in period 2, why do firms invest in quality improvement to snatch them? Quality investment is mainly for those regular customers, which are only a proportion of the total customers. This induces firms' low quality levels compared to that without variety seeking customers. Regarding the firms' price decisions, we show that, in period 2, the existence of variety seeking customers results in a lower retail price. The underlying reason is that, firms have to set a low retail price to prevent some regular and variety seeking customers from transferring to the rival's product. This intensifies the price competition in period 2, because firms only maximize their profits in period 2. However, an interesting finding is that, firms' retail prices in period 1 are not necessarily low. It depends on the effort cost coefficient. When the effort cost coefficient is sufficiently small, quality improvement is not costly. To snatch more customers, firms decide a low retail price. However, when the effort cost coefficient is sufficiently large, firms have to charge a high price to compensate the quality cost.

We further compare firms' profits in three market structures. Interestingly, we show that, firms are worse off in a mixed market of both regular and variety seeking customers, when the effort cost coefficient is small. We also study customer surplus and find that, the more variety seeking customers in the market, the smaller customer surplus in period 1 is. However, the existence of variety seeking customers can increase the customer surplus in period 2. When the effort cost coefficient is in a moderate range, the regular and variety seeking customers reach a win-win solution by both enjoying a high customer surplus.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. In Section 3, we present the model settings and the assumptions. We analyze firms' price and quality decisions in Section 4. Section 5 discusses the impact of variety seeking customers on customer surplus, and the outcomes when one firm imports products of high-quality. Section 6 concludes this paper. All the proofs are in the online Appendix.

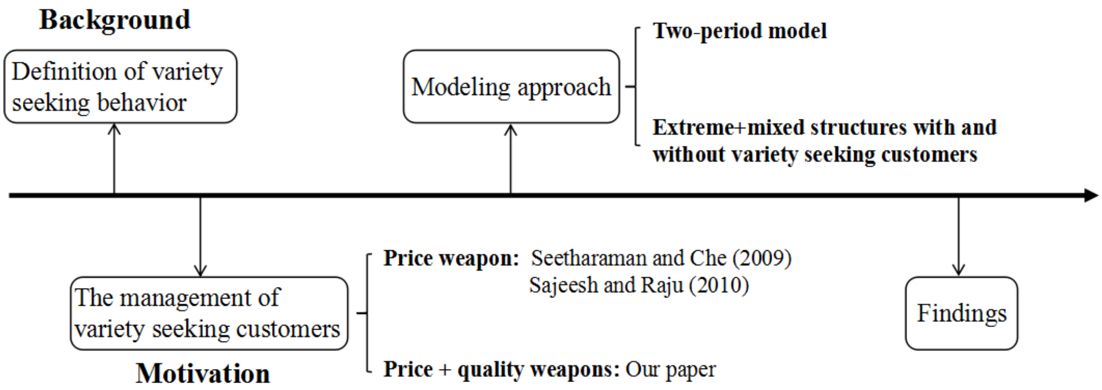

Figure 1 The Organization of Introduction Section

2 Literature Review

There are three research streams that are most relevant to our study, namely variety seeking behavior, pricing strategy, and multi-period decisions.

The first stream is about variety seeking behavior. Bawa (1990) builds a choice model to investigate the inertia and variety seeking behavior within the same individual. Feinberg et al. (1992) investigate the impact of variety seeking intensity and brand preferences on a firm's long-term market share. They show that, the brand which is more preferred before will lose market share as the variety seeking intensity increases. Woratschek and Horbel (2006) study the impact of variety seeking behavior on a firm's profit and consumer surplus. They show that the variety seeking behavior is harmful to the firm's profit but is beneficial to consumer surplus. Our study is closely related to two representative marketing papers on variety seeking customers. Seetharaman and Che (2009) investigate the impact of variety seeking customers on price competition in an inertial market, and show that price competition might be softened in two periods. Song et al. (2018) investigate the impact of Chinese customers' variety seeking behavior on their intercity travelers' mode choice decisions. In particular, our paper is most relevant to Sajeesh and Raju (2010), which assumes firms can determine their products differentiation. Regarding the firms' price decisions, they show that firms decide high prices in period 1 but low prices in period 2. Different from their works, we involve firms' quality decisions by assuming effort-dependent cost. We find that whether the price in period 1 is high or low depends on the effort cost coefficient, in a threshold way. We also show that customer surplus of both regular and variety seeking customers can be reduced, which is significantly different from Sajeesh and Raju (2010).

Our paper is also related to studies on pricing strategy. Most previous literature of this stream is based on single period models. For example, Hua et al. (2010) consider a dual channel model and investigate the impact of deliver lead time in the direct channel on firm's pricing decision. Wang et al. (2013) investigate a dominant retailer's joint decisions of pricing and timing of sales effort investment. Hsieh et al. (2014) study the pricing and ordering decisions when several manufacturers sell substitutable products through a common retailer. Ding et al. (2016) study the hierarchical pricing decision process for a manufacturer and a retailer in a dual-channel framework. Shen et al. (2016) focus on design outsourcing decision and examine the impact of pricing schemes on design innovation and supply chain coordination. Choi (2017) studies the pricing and brand investment decisions of typical business operations that many fashion companies collect, recycle and sell remanufactured fashion products. However, few studies focus on pricing strategies in multi-period models with the consideration of customer behaviors. Representative works include Gans (2002), Aflaki and Popescu (2014), Zhang and Niu (2014), Xue et al. (2015), etc. Specifically, Gans (2002) assumes that customers use Bayesian updating to learn the suppliers' service quality, and studies the competing suppliers' corresponding service quality decisions. Aflaki and Popescu (2011) notice that customers' retention is affected by their past purchasing experiences, and build a multi-period model to maximize customers' lifetime value. Zhang and Niu (2014) develop a dynamic quality decision-making model to study the impact of customer perception. Xue et al. (2015) involve decision maker's risk attitudes and design inventory and hedging schemes under CVaR measures. Differently, we focus on the joint optimization of price and quality level decisions in a Hotelling model. We are interested in how customers' variety seeking behavior influences the firms' price decisions in two periods.

There is a growing amount of studies considering firms' multi-period decisions. Bhattacharjee and Ramesh (2000) consider the multi-period inventory and pricing problems for perishable products. Matsuyama (2006) investigates the ordering plan in a multi-period model with the consideration of unsatisfied demand and unsold quantity. Zhang et al. (2009) build convex stochastic programming models to solve the single and multi-period inventory control problems with demand uncertainty. Ma et al. (2012) allow two ordering opportunities for a newsvendor and study the impact of demand information updating. Chen et al. (2013) study the optimal inventory policy when there is a spot market. Xue et al. (2016) extend Xue et al. (2015) by studying random yield supply and identifying the impact of a risk-sensitive manufacturer. Different from their works, we build a two-period model and focus on customers' pricing policies when they are variety seeking. We identify new drivers for firms to invest in quality improvement.

To summarize, the related studies are shown in Table 1. It is clear that our paper is the one that comprehensively studies variety seeking behavior, pricing strategy, multi-period decisions and quality decision.

Table 1: Position of Our Work in Literature

Literatures	*Variety seeking behavior*	*Pricing strategy*	*Multi-period decisions*	*Quality decision*
Bhattacharjee and Ramesh(2000)		√	√	
Gans (2002)	√			√
Seetharaman and Che (2009)	√	√	√	
Zhang et al. (2009)			√	
Hua et al. (2010)		√		
Sajeesh and Raju (2010)	√	√	√	
Aflaki and Popescu (2011)	√	√	√	
Zhang and Niu (2014)		√	√	√
Choi. (2017)		√		√
Our paper	√	√	√	√

3 Model Settings

Based on the Hotelling model (Hotelling 1929), we consider two symmetric firms (A and B) competing in the market. We assume the customers are uniformly distributed on a unit interval $[0,1]$ and the two firms are located at point 0 and point 1, respectively. Customers either buy product A or product B, depending on their net utilities for the product. Each firm can make effort to improve the product's quality level. Without loss of generality, the effort cost is $\frac{\beta v_i^2}{2}(i \in \{A, B\}, \beta > 0)$(Wang and Shin, 2015), where β represents the effort cost coefficient (quality innovation efficiency) and v represents the product's quality level. The unit production cost c is related to the quality level, that is, $c = \alpha v_i(i \in \{A, B\}, 0 < \alpha < 1)$. This assumption is consistent with the common sense that it takes more cost to produce high quality products. Given a specific customer's location $x(x \in [0,1])$, the customer's net utility of buying product

A is $U_A = v_A - mx - p_A$[1], and that of buying product B is $U_B = v_B - m(1-x) - p_B$, where $m(m > 0)$ represents the unit mismatch cost. If $U_A > U_B$, the customer will select product A, otherwise, it will select product B.

We consider a two-period model where there might be variety seeking customers. In period 1, the variety seeking customers are identical to the regular customers. However, in period 2, the variety seeking customers incur a distaste cost Δ for the product they purchased in period 1. See Figure 2 for an illustration. A and B represent the two firms' respective demand in period 1. In period 2, AS and BS represent the demand of the variety seeking customers who still purchase the product they purchased in period 1, while AT and BT represent the demand of the variety seeking customers who transfer their preferences from product A (B) to product B (A)

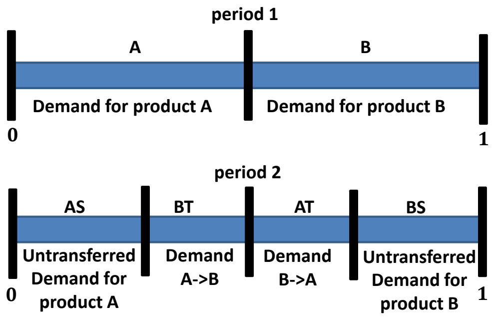

Figure 2 Demand in Period 1 and 2

According to the fraction of variety seeking customers in the market, we investigate three market structures. Structure X represents that the market is full of regular customers; Structure Y represents that the market is mixed by regular and variety seeking customers. The fraction of variety seeking customers is denoted by $\theta, 0 < \theta < 1$; Structure Z represents that the market is full of variety seeking customers. Note that, Structure X and Structure Z are special cases for Structure Y where $\theta = 0$ and $\theta = 1$, respectively.

The decision sequence is illustrated in Figure 3.

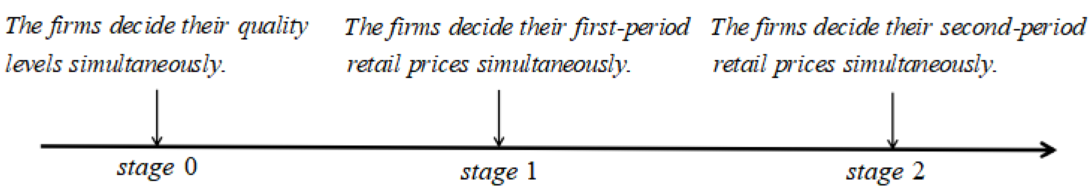

Figure 3 The Decision Sequence

In stage 0, the firms decide the quality levels and incur the corresponding effort cost $\frac{\beta v_i^2}{2}$ $(i \in \{A, B\})$. In stage 1, given the realized quality level, the firms decide the first-period

[1] Here, we follow Wang and Shin (2015) by assuming the upper bound of a customer's utility is the product's quality level.

retail prices. In stage 2, the firms decide the second-period retail prices. The customers buy the product which maximizes their net utilities.

We summarize all notations in Table 2 for the ease of reference.

Table 2 Notations

Δ	Distaste cost for the product purchased previously
v_i	Product i's quality level, $i \in \{A, B\}$
m	Unit mismatch cost
α	Production cost coefficient
β	Effort cost coefficient
c	Unit production cost
θ	The fraction of variety seeking customers in the market
$p_{i,j}^{M}$	Product i's price in Period j(under Structure M), $i \in \{A, B\}$, $j \in \{1,2\}$ and $M \in \{X, Y, Z\}$
$q_{i,j}^{M}$	Product i's demand in Period j(under Structure M), $i \in \{A, B\}$, $j \in \{1,2\}$ and $M \in \{X, Y, Z\}$
$U_{i,j}^{M}$	Customer i's net utility in period j(under Structure M), $i \in \{A, B\}$, $j \in \{1,2\}$ and $M \in \{X, Y, Z\}$
$U_{iS,2}^{Y}\left(U_{iT,2}^{Y}\right)$	Customer iS's (iT's) net utility in period 2(under Structure Y), $i \in \{A, B\}$
$\pi_{i,j}^{M}$	Firm i's profit in Period j(under Structure M), $i \in \{A, B\}$, $j \in \{1,2\}$ and $M \in \{X, Y, Z\}$
$\pi_{i,Total}^{M}$	Firm i's total profit(under structure M), $i \in \{A, B\}$ and $M \in \{X, Y, Z\}$
$CS_{R,j}^{M}$	Customer surplus of a regular customer in period j(under Structure M), $j \in \{1,2\}$ and $M \in \{X, Y\}$
$CS_{R,Total}^{M}$	Total customer surplus of regular customers (under Structure M), $M \in \{X, Y\}$
$CS_{S,j}^{M}$	Customer surplus of a variety seeking customer in period j(under Structure M), $j \in \{1,2\}$ and $M \in \{Y, Z\}$
$CS_{S,Total}^{M}$	Total customer surplus of variety seeking customers (under Structure M), $M \in \{Y, Z\}$

4 Analysis of Basic Models

In this section, we solve the three-stage game by backward induction. We first derive the equilibrium outcomes under three structures, respectively. To guarantee the positive profits for the two firms, we assume that $m > \Delta$ and $\beta > \frac{13(1-\alpha)^2}{50m}$. We further define $\underline{\beta} = \frac{13(1-\alpha)^2}{50m}$.

4.1 Structure Y

In Structure Y, the market is mixed by regular and variety seeking customers. They are uniformly distributed on interval [0,1].

In period 1, the distasted cost has not incurred, so there is no difference between regular and variety seeking customers. We divide the customers in period 1 into two types: (1)

Customers A are the customers who purchased product A; (2) Customers B are the customers who purchased product B. Their net utilities are

$$U_{A,1} = v_A - m\,x - p_{A,1};$$

$$U_{B,1} = v_B - m\,(1-x) - p_{B,1}.$$

In period 2, the regular customers' utility won't be affected by their purchasing behavior in period 1, while the variety seeking customers incur a distaste cost Δ for the product they purchased in period 1. We divide the customers in period 2 into six types: (1) Customers A are the regular customers who purchase product A in period 2; (2) Customers B are the regular customers who purchase product B in period 2; (3) Customers AS are the variety seeking customers who purchased product A in period 1 and still purchase product A in period 2; (4) Customers BT are the variety seeking customers who purchased product A in period 1 and purchase product B in period 2; (5) Customers AT are the variety seeking customers who purchased product B in period 1 and purchase product A in period 2; (6) Customers BS are the variety seeking customers who purchased B in period 1 and still purchase product B in period 2. Their net utilities are:

$$U_{A,2} = v_A - m\,x - p_{A,2};$$

$$U_{B,2} = v_B - m\,(1-x) - p_{B,2};$$

$$U_{AS,2} = v_A - \Delta - m\,x - p_{A,2};$$

$$U_{BT,2} = v_B - m\,(1-x) - p_{B,2};$$

$$U_{AT,2} = v_A - mx - p_{A,2};$$

$$U_{BS,2} = v_B - \Delta - m\,(1-x) - p_{B,2}.$$

Figure 4 illustrates the customers' distribution.

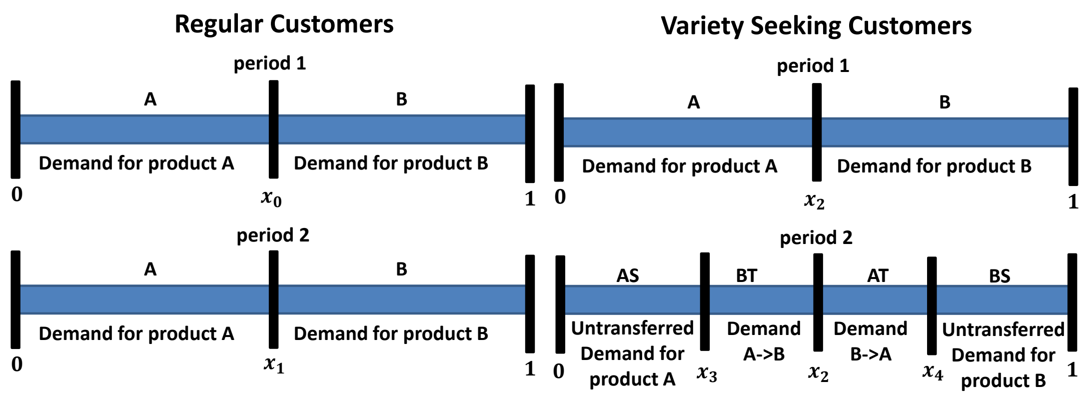

Figure 4 The Market Distribution in Structure Y

In period 1, we solve $U_{A,1} = U_{B,1}$ and derive regular (variety seeking) customers' indifferent point in period 1:

$$x_0 = \frac{m+v_A-v_B-p_{A,1}+p_{B,1}}{2m} \left(x_2 = \frac{m+v_A-v_B-p_{A,1}+p_{B,1}}{2m}\right).$$

In period 2, we solve $U_{A,2}=U_{B,2}, U_{AS,2}=U_{BT,2}, U_{AT,2}=U_{BS,2}$ and derive the indifferent points

$$x_1=\frac{m+v_A-v_B-p_{A,2}+p_{B,2}}{2m};$$
$$x_3=\frac{m-\Delta+v_A-v_B-p_{A,2}+p_{B,2}}{2m};$$
$$x_4=\frac{m+\Delta+v_A-v_B-p_{A,2}+p_{B,2}}{2m}.$$

Note that the fraction of variety seeking customers is θ. We derive the firms' demand in each period as follows:

$$q_{A,1}=(1-\theta)x_0+\theta x_2=\frac{m+v_A-v_B-p_{A,1}+p_{B,1}}{2m};$$
$$q_{B,1}=(1-\theta)(1-x_0)+\theta(1-x_2)=\frac{m-v_A+v_B+p_{A,1}-p_{B,1}}{2m};$$
$$q_{A,2}=(1-\theta)x_1+\theta x_3+\theta(x_4-x_2)$$
$$=\frac{m+m\theta+v_A+\theta v_A-v_B-\theta v_B-2m\theta x_2-p_{A,2}-\theta p_{A,2}+p_{B,2}+\theta p_{B,2}}{2m};$$
$$q_{B,2}=(1-\theta)(1-x_1)+\theta(x_2-x_3)+\theta(1-x_4)$$
$$=\frac{m-m\theta-v_A-\theta v_A+v_B+\theta v_B+2m\theta x_2+p_{A,2}+\theta p_{A,2}-p_{B,2}-\theta p_{B,2}}{2m}.$$

We use backward induction to solve this game.

In Stage 2, the two firms' objective functions are their profits in period 2, i.e.

$$\pi_{A,2}=\left(p_{A,2}-\alpha v_A\right)q_{A,2}=\frac{(p_{A,2}-\alpha v_A)[m(1+\theta-2\theta x_2)+(1+\theta)(v_A-v_B-p_{A,2}+p_{B,2})]}{2m};$$
$$\pi_{B,2}=\left(p_{B,2}-\alpha v_B\right)q_{B,2}=\frac{(p_{B,2}-\alpha v_B)[m(1-\theta+2\theta x_2)+(1+\theta)(-v_A+v_B+p_{A,2}-p_{B,2})]}{2m}.$$

It is easy to verify that $\pi_{A,2}(\pi_{B,2})$ is concave in $p_{A,2}(p_{B,2})$. Thus the retail prices are

$$p_{A,2}=\frac{(1+2\alpha)(1+\theta)v_A-(1-\alpha)(1+\theta)v_B+m(3+\theta-2\theta x_2)}{3(1+\theta)};$$
$$p_{B,2}=\frac{-(1-\alpha)(1+\theta)v_A+(1+2\alpha)(1+\theta)v_B+m(3-\theta+2\theta x_2)}{3(1+\theta)}.$$

In stage 1 and 0, the two firms' objective functions are the sum of their profits in two periods, which are given as follows.

$$\pi_{A,1}+\pi_{A,2}=\left(p_{A,1}-\alpha v_A\right)q_{A,1}+\left(p_{A,2}-\alpha v_A\right)q_{A,2}-\frac{\beta v_A^2}{2} \quad (1)$$
$$\pi_{B,1}+\pi_{B,2}=\left(p_{B,1}-\alpha v_B\right)q_{B,1}+\left(p_{B,2}-\alpha v_B\right)q_{B,2}-\frac{\beta v_B^2}{2}. \quad (2)$$

Taking the first derivative of (1) and (2) with respect to $p_{A,1}$ and $p_{B,1}$, respectively, we obtain the retail price decisions.

$$p_{A,1}=\frac{m(3+5\theta)(27+27\theta-4\theta^2)+3(1+\theta)[9+11\theta+2\alpha(9+8\theta-2\theta^2)]v_A-3(1-\alpha)(1+\theta)(9+11\theta)v_B}{3(1+\theta)(27+27\theta-4\theta^2)};$$
$$p_{B,1}=\frac{m(3+5\theta)(27+27\theta-4\theta^2)-3(1-\alpha)(1+\theta)(9+11\theta)v_A+3(1+\theta)[9+11\theta+2\alpha(9+8\theta-2\theta^2)]v_B}{3(1+\theta)(27+27\theta-4\theta^2)}.$$

Substituting $p_{A,1}$ and $p_{B,1}$ into their objective functions, we have the equilibrium outcomes, see Lemma 1.

Lemma 1.

In Structure Y,

(1) The quality levels are $v_A^Y = v_B^Y = \frac{(1-\alpha)(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$;

(2) The retail prices are $p_{A,1}^Y = p_{B,1}^Y = \frac{m(3+5\theta)}{3(1+\theta)} + \frac{\alpha(1-\alpha)(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$, $p_{A,2}^Y = p_{B,2}^Y = \frac{m}{1+\theta} + \frac{\alpha(1-\alpha)(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$;

(3) The profits are $\pi_{A,1}^Y = \pi_{B,1}^Y = \frac{m(3+5\theta)}{6(1+\theta)} - \frac{(1-\alpha)^2(6-\theta)^2(9+10\theta)^2}{18\beta(27+27\theta-4\theta^2)^2}$, $\pi_{A,2}^Y = \pi_{B,2}^Y = \frac{m}{2+2\theta}$, $\pi_{A,Total}^Y = \pi_{B,Total}^Y = \frac{m(6+5\theta)}{6(1+\theta)} - \frac{(1-\alpha)^2(6-\theta)^2(9+10\theta)^2}{18\beta(27+27\theta-4\theta^2)^2}$.

4.2 Structure X and Z

In Structure X (Z), the market is full of regular (variety seeking) customers. As mentioned in the previous section, Structure X (Z) is the special case where $\theta = 0$ ($\theta = 1$). Therefore, we omit the derivation for simplicity. Substituting $\theta = 0$ ($\theta = 1$) into the outcomes in Lemma 1, we obtain the following outcomes.

Lemma 2.

In Structure X,

(1) The quality levels are $v_A^X = v_B^X = \frac{2(1-\alpha)}{3\beta}$;

(2) The retail prices are $p_{A,1}^X = p_{B,1}^X = p_{A,2}^X = p_{B,2}^X = m + \frac{2\alpha(1-\alpha)}{3\beta}$;

(3) The profits are $\pi_{A,1}^X = \pi_{B,1}^X = \frac{m}{2} - \frac{2(1-\alpha)^2}{9\beta}$, $\pi_{A,2}^X = \pi_{B,2}^X = \frac{m}{2}$, $\pi_{A,Total}^X = \pi_{B,Total}^X = m - \frac{2(1-\alpha)^2}{9\beta}$.

Lemma 3.

In Structure Z,

(1) The quality levels are $v_A^Z = v_B^Z = \frac{19(1-\alpha)}{30\beta}$;

(2) The retail prices are $p_{A,1}^Z = p_{B,1}^Z = \frac{4m}{3} + \frac{19\alpha(1-\alpha)}{30\beta}$, $p_{A,2}^Z = p_{B,2}^Z = \frac{m}{2} + \frac{19\alpha(1-\alpha)}{30\beta}$;

(3) The profits are $\pi_{A,1}^Z = \pi_{B,1}^Z = \frac{2m}{3} - \frac{361(1-\alpha)^2}{1800\beta}$, $\pi_{A,2}^Z = \pi_{B,2}^Z = \frac{m}{4}$, $\pi_{A,Total}^Z = \pi_{B,Total}^Z = \frac{11m}{12} - \frac{361(1-\alpha)^2}{1800\beta}$.

4.3 Analysis of the outcomes in three structures

In this section, we first analyze the marginal profits of the two periods, respectively. Then, we focus on the quality and price decisions for the two firms. At last, we compare the total profits among three structures. Comparing the marginal profits among three structures, we have Lemma 4.

Lemma 4.

(1) $p_{i,2}^{Z}-\alpha v_i^{Z}<p_{i,2}^{Y}-\alpha v_i^{Y}<p_{i,2}^{X}-\alpha v_i^{X}$;

(2) $p_{i,1}^{X}-\alpha v_i^{X}<p_{i,1}^{Y}-\alpha v_i^{Y}<p_{i,1}^{Z}-\alpha v_i^{Z}$.

We review firm A's demand function as an example, i.e.

$q_{A,2}=\frac{m(1+\theta-2\theta x_2)+(1+\theta)(v_A-v_B-p_{A,2}+p_{B,2})}{2m}$.

It's easy to have

$$\frac{dq_{A,2}}{dp_{A,2}}=-\frac{1+\theta}{2m},$$

That is, in period 2, firm A reduces one unit market price of product A, can attract more customers when the fraction of variety seeking customers is high. In other words, a high fraction of variety seeking customers induces firm A to have more incentives to lower the price in period 2. This results in a fierce price competition. Possible explanations are as follows: (1) The variety seeking customers who purchased product A in period 1 will easily change to product B in period 2 due to the boredom cost. A lower price of product A is necessary to reduce the loss of "old" customers; (2) Because of the boredom cost, the variety seeking customers who purchased product B in period 1 will be hesitating to choose product A or B in period 2. A lower price of product A can easily attract more this type of customers. As a result, firm A is willing to set a low markup in a market with high fraction of variety seeking customers. This explains Lemma 4 (1).

Also we find,

$$\frac{dq_{A,2}}{d\,x_2}=-\theta,$$

which means: (1) A high demand in period 1 will induce a low demand in period 2 (note that $q_{A,1}=x_2$); (2) The demand in period 1 has a large impact on the demand in period 2, when the fraction of variety seeking customers is high. The reason is clear: variety seeking customers who purchased product A in period 1 have more incentives to purchase product B in period 2. For firm A, a high price of product A in period 1 makes him earn more. However, his demand will decrease in period 1, and the lost demand will be compensated in period 2. Therefore, firm A has more incentives to raise price in period 1, when the fraction of variety seeking customers is high. This results in a mild competition in period 1. As a result, firm A is willing to set a high markup from in a market of high fraction variety seeking customers. This explains Lemma 4 (2).

We define two effects for the ease of explanation: (1) *competition intensification effect*: as the fraction of variety seeking customers increases, the competition in period 2 becomes fiercer; (2) *competition mitigation effect*: as the fraction of variety seeking customers increases, the competition in period 1 becomes milder.

To further investigate the firms' quality decisions, we derive Proposition 1.

Proposition 1.

$v_i^Z < v_i^Y < v_i^X, i \in \{A, B\}$.

Proposition 1 indicates that, a high fraction of variety seeking customers will reduce firms' incentives to improve the product quality. Taking firm A as an example, we explain this finding from three aspects: (1) Indeed, a high quality level can attract more customers. In period 1, the boredom cost does not appear, the high quality is effective to attract customers. In period 2, as discussed previously, the large demand in period 1 induces high quality to be not effective, due to the existence of variety seeking customers. (2) A high quality level means a high cost (including effort cost and production cost). Note that, in period 2, the price competition is fierce when the variety seeking customers exit. Therefore, a high production cost will make firm A passive in period 2. (3) Quality and price are two weapons to attract customers; however, quality is determined before price and will not be adjusted in period 2. In contrast, price is more feasible and effective to deal with customers' variety seeking behavior, because firms make price decisions in both period 1 and period 2.

Due to above analysis, firm A has less incentives to improve product quality when the fraction of variety seeking customers is high, which results in a milder competition in quality. The milder completion in quality indicates low effort cost and production cost. We define them as two effects: (1) *production cost reduction effect*: as the fraction of variety seeking customers increases, the production cost decreases; (2) *effort cost reduction effect*: as the fraction of variety seeking customers increases, the effort cost decreases.

Next, we investigate the firms' pricing strategies and firms' total profits in the two periods. Intuitively, the price in Structure Y should be between the prices in Structure X and Z. However, we derive an interesting finding that the price in period 1 and Structure Y is not necessarily in the middle.

Define $\beta_1 = \frac{\alpha(1-\alpha)(1+\theta)(3+2\theta)}{2m(27+27\theta-4\theta^2)}$, $\beta_2 = \frac{\alpha(1-\alpha)}{10m}$ and $\beta_3 = \frac{3\alpha(1-\alpha)(1+\theta)(9+8\theta)}{10m(27+27\theta-4\theta^2)}$, where $0 < \beta_1 < \beta_2 < \beta_3 < +\infty$. We have Proposition 2.

Proposition 2.

(1) $p_{i,2}^Z < p_{i,2}^Y < p_{i,2}^X$, $i \in \{A, B\}$;

(2) (a) When $\beta \le \beta_1$, we have $p_{i,1}^Z < p_{i,1}^Y \le p_{i,1}^X, i \in \{A, B\}$;

(b) When $\beta_1 < \beta \le \beta_2$, we have $p_{i,1}^Z \le p_{i,1}^X < p_{i,1}^Y, i \in \{A, B\}$;

(c) When $\beta_2 < \beta \le \beta_3$, we have $p_{i,1}^X < p_{i,1}^Z \le p_{i,1}^Y, i \in \{A, B\}$;

(d) When $\beta > \beta_3$, we have $p_{i,1}^X < p_{i,1}^Y < p_{i,1}^Z, i \in \{A, B\}$.

Proposition 2(1) indicates that, a high fraction of the variety seeking customers leads to a low retail price in period 2. Note that, the retail price is determined with the consideration of production cost and profit margin. As we have defined, competition intensification effect and production cost reduction effect both induce a low retail price when the fraction of the variety seeking customers is high.

We then discuss the findings in Proposition 2(2), which shows the comparative results of the retail prices in period 1. In a market having a high fraction of variety seeking customers, there exist both competition mitigation effect and production cost reduction effect. The former increases the price in period 1, while the latter decreases the price in period 1. As the effort cost coefficient β increases, improving quality is less efficient, forcing firms to further lower the quality and save effort costs, which enhances the production cost reduction effect.

Compared to Structure X, Structure Z has a higher fraction of variety seeking customers. When the effort cost coefficient is large, production cost reduction effect dominates competition mitigation effect in Structure Z, so the price in period 1 in Structure Z is higher than that in Structure X. When the effort cost coefficient is small, competition mitigation effect dominates production cost reduction effect, so the price in period 1 in Structure Z is lower than that in Structure X.

Structure Y has a higher fraction of variety seeking customers than Structure X, while a lower fraction of variety seeking customers than Structure Z. Similar to above analysis, the price in period 1 in Structure Y is higher when the effort cost coefficient is large, while higher than that in Structure Z when the effort cost coefficient is small. Interestingly, when the effort cost coefficient is in a moderate range, the price in period 1 in Structure Y is higher than that in Structure X and Z, which is counterintuitive.

We further compare the firms' profits among three structures. Define $\beta_4 = \frac{(1-\alpha)^2(1+\theta)(9+8\theta)\left(1053+10230\theta-176\theta^2\right)}{50m(27+27\theta-4\theta^2)^2}$, where $\underline{\beta} < \beta_4 < +\infty$. We have the following proposition.

Proposition 3.

(1)When $\beta \leq \beta_4$, we have $\pi_{i,Total}^{Y} \leq \pi_{i,Total}^{Z} < \pi_{i,Total}^{X}, i \in \{A, B\}$;

(2)When $\beta > \beta_4$, we have $\pi_{i,Total}^{Z} \leq \pi_{i,Total}^{Y} < \pi_{i,Total}^{X}, i \in \{A, B\}$;

In a market having a high fraction of variety seeking customers, there exist competition mitigation effect, competition intensification effect and effort cost reduction effect. Competition mitigation effect improves firms' profits in period 1, while competition intensification effect reduces firms' profits in period 2. Effort cost reduction effect can reduce firms' cost, which is beneficial for the firms.

By Lemma 1, it's easy to check

$$\frac{d\left[p_{i,1}^{Y}+p_{i,2}^{Y}-2\alpha v_i^{Y}\right]}{d\,\theta} = -\frac{m}{3(1+\theta)^2} < 0,$$

which means the competition intensification effect always dominates the competition mitigation effect.

By Proposition 1, we know that a high fraction of variety seeking customers indicates a low quality level. As the effort cost coefficient β increases, firms have incentives to lower the quality level, which makes the effort cost reduction effort less significant.

Note that, the total profit in structure X is always larger than that in structure Y or Z. Compared to Structure X, Structure Y and Z have variety seeking customers. Therefore, the competition intensification effect dominates “competition mitigation effect” + “effort cost reduction effect”. As a result, the total profit in Structure Y or Z is lower than that in Structure X. Our finding can be practical. For example, an empirical literature Woratschek and Horbel (2006) shows that, the existence of variety seeking customers is harmful to firms’ profits. Interestingly, when the effort cost coefficient is small, the total profit in Structure Y is lower than that in either X or Z, which is counterintuitive.

The reason is that, the mixed customers cause the firms to lose the price flexibility. Therefore, the firms can’t set the retail prices for both regular and variety seeking customers at their most preferred levels. As a result, the firms’ profits are injured when the market is mixed by regular and variety seeking customers. To avoid this hurt, firms are suggested to identify these two types of customers and provide different discounts to the variety seeking customers in period 2.

5 Extensions

5.1 Analysis of Customer Surplus

In the previous section, we analyze firms’ decisions and profits in three market structures. In this section, we analyze the customer’s preferences by comparing the customer surplus.

For the regular customers, the customer surplus in period 1 is $CS_{R,1} = \int_0^{x_0} U_{A,1}\,dx + \int_{x_0}^1 U_{B,1}\,dx$, that in period 2 is $CS_{R,2} = \int_0^{x_1} U_{A,2}\,dx + \int_{x_1}^1 U_{B,2}\,dx$. The total customer surplus is $CS_{R,Total} = CS_{R,1} + CS_{R,2}$. For the variety seeking customers, the customer surplus in period 1 is $CS_{S,1} = \int_0^{x_2} U_{A,1}\,dx + \int_{x_2}^1 U_{B,1}\,dx$, that in period 2 is $CS_{S,2} = \int_0^{x_4} U_{AS,2}\,dx + \int_{x_4}^{x_3} U_{BT,2}\,dx + \int_{x_3}^{x_5} U_{AT,2}\,dx + \int_{x_5}^1 U_{BS,2}\,dx$. The total customer surplus is $CS_{S,Total} = CS_{S,1} + CS_{S,2}$.

The customer surplus in each structure is summarized in the following lemma.

Lemma 5.

(1)The customer surplus in Structure X is

$$CS_{R,1}^X = -\frac{5m}{4} + \frac{2(1-\alpha)^2}{3\beta},\ CS_{R,2}^X = -\frac{5m}{4} + \frac{2(1-\alpha)^2}{3\beta},\ CS_{R,Total}^X = -\frac{5m}{2} + \frac{4(1-\alpha)^2}{3\beta}.$$

(2)The customer surplus in Structure Y is

$$CS_{R,1}^Y = -\frac{m(15+23\theta)}{12} + \frac{(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)},\quad CS_{R,2}^Y = -\frac{m(5+\theta)}{4(1+\theta)} + \frac{(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)},$$

$$CS_{R,Total}^Y = -\frac{m(15+13\theta)}{6(1+\theta)} + \frac{2(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)};$$

$CS^Y_{S,1} = -\frac{m(15+23\theta)}{12(1+\theta)} + \frac{(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$, $CS^Y_{S,2} = -\frac{m^2(5+\theta)+4m\Delta(1+\theta)-2\Delta^2(1+\theta)}{4m(1+\theta)} + \frac{(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$, $CS^Y_{S,Total} = -\frac{m^2(15+13\theta)+6m\Delta(1+\theta)-3\Delta^2(1+\theta)}{6m(1+\theta)} + \frac{2(1-\alpha)^2(6-\theta)(9+10\theta)}{3\beta(27+27\theta-4\theta^2)}$.

(3)The customer surplus in Structure Z is

$CS^Z_{S,1} = \frac{38(1-\alpha)^2-95m\beta}{60\beta}$, $CS^Z_{S,2} = \frac{38m(1-\alpha)^2-45m^2\beta-60m\beta\Delta+30\beta\Delta^2}{60m\beta}$, $CS^Z_{S,Total} = \frac{38m(1-\alpha)^2-70m^2\beta-30m\beta\Delta+15\beta\Delta^2}{30m\beta}$.

We first focus on the regular customers by comparing the customer surplus between Structure X and Structure Y. Define $\beta_5 = \frac{2(1-\alpha)^2(1+\theta)(3+2\theta)}{m(27+27\theta-4\theta^2)}$. We have the following proposition.

Proposition 4.

(1) $CS^X_{R,1} > CS^Y_{R,1}$;

(2) $CS^X_{R,2} < CS^Y_{R,2}$;

(3) $CS^X_{R,Total} > CS^Y_{R,Total}$, iff $\beta < \beta_5$.

Note that, the quality level and the retail price are two key factors which determine the customer surplus. Higher quality level and a low retail price lead to a large customer surplus. In period 1, we find that the regular customers always benefit in Structure X. Recall that, the quality level in Structure X is always higher than that in Structure Y(i.e. $v^Y_i < v^X_i$), while only when β is sufficiently small(i.e. $\beta \le \beta_1$) would the retail price in Structure X is higher than that in Structure Y. When β is sufficiently small, the quality level difference is significant. Therefore, the impact of the quality level dominates the impact of the retail price, making the regular customers always benefit in Structure X. However, in period 2, the retail price in Structure X is always higher than that in Structure Y (i.e. $p^Y_{i,2} < p^X_{i,2}$). In this stage, the impact of the retail price dominates that of the quality level and thus, the regular customers are injured in Structure Y. Regarding the total customer surplus, when β is small(i.e. $\beta < \beta_5$), the benefit in the period 1 can cover the hurt in period 2 for the regular customers in Structure X. As a result, the total customer surplus for regular customers is larger in Structure X than that in Structure Y when β is small. Otherwise, the revised outcome holds.

We then analyze the customer surplus of the variety seeking customers by comparing Structure Y and Z. Define $\beta_6 = \frac{6(1-\alpha)^2(1+\theta)(9+8\theta)}{5m(27+27\theta-4\theta^2)}$. We obtain Proposition 5.

Proposition 5.

(1) $CS^Y_{S,1} > CS^Z_{S,1}$;

(2) $CS^Y_{S,2} < CS^Z_{S,2}$;

(3) $CS^Y_{S,Total} > CS^Z_{S,Total}$, iff $\beta < \beta_6$

Interestingly, we find that when $\beta \in (\beta_5, \beta_6)$, both regular and variety seeking customers benefit in Structure Y (i.e. $CS^{Y}_{S,Total} > CS^{Z}_{S,Total}$ and $CS^{Y}_{R,Total} < CS^{X}_{R,Total}$). Possible reason is that, when β is in a moderate range, the firms are hurt by losing the price flexibility, which benefits the customers.

5.2 Impact of Imported Overseas Products

In the basic model, we assume that the two firms both make efforts to improve the product's quality level. In this subsection, we consider a case where one firm (Firm A) invests in quality while the other firm (Firm B) imports high-quality products by paying a fixed sourcing cost and the tariff. Without loss of generality, we assume the quality of imported products is high, noted as v_H. The unit sourcing cost and the tariff rate are noted as c_H and r, respectively. In other words, firm B will pay $(1+r)c_H$ for unit imported product and it can avoid the effort cost for quality improvement. For simplicity, we define $C = (1+r)c_H$. The decision sequence is illustrated in Figure 5.

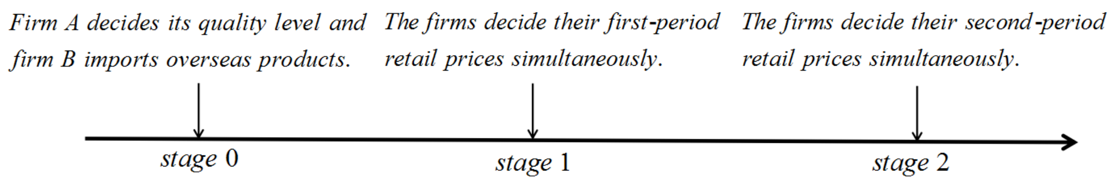

Figure 5 The Decision Sequence

We omit the solving details. Note that, firm B's profit functions become $\pi_{B,1} = (p_{B,1} - C)q_{B,1}$ and $\pi_{B,2} = (p_{B,2} - C)q_{B,2}$, rather than $\pi_{B,1} = (p_{B,1} - \alpha v_B)q_{A,1} - \frac{\beta v_B^2}{2}$ and $\pi_{B,2} = (p_{B,2} - \alpha v_B)q_{B,2}$. It is challenging to obtain the analytical solutions, so we illustrate the main results via numerical studies. Let $\alpha = \frac{1}{2}$, $C = \frac{1}{10}$, $v_H = 2$, $\theta = \frac{1}{2}$ and $m = \frac{13(1-\alpha)^2}{50\beta} + 3$.

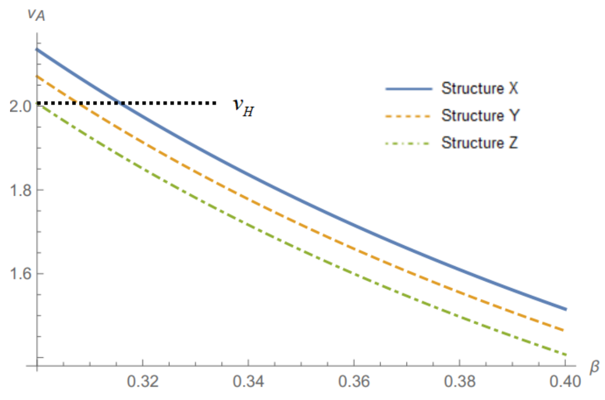

Figure 6 Firm A's Quality Levels in Different Structures

Figure 6 shows firm A's equilibrium quality levels in three structures. We observe that, the existence of variety seeking customers leads to a low quality level, which is similar to the finding in the basic model. We observe that, when β is small, firm A might improve its quality level to be higher than v_H. This encourages Chinese firms such as firm A to invest in technology to lower β and improve quality innovation efficiency. This observation is significantly different from that both firms invest in quality as Proposition 3, where a small β can be harmful.

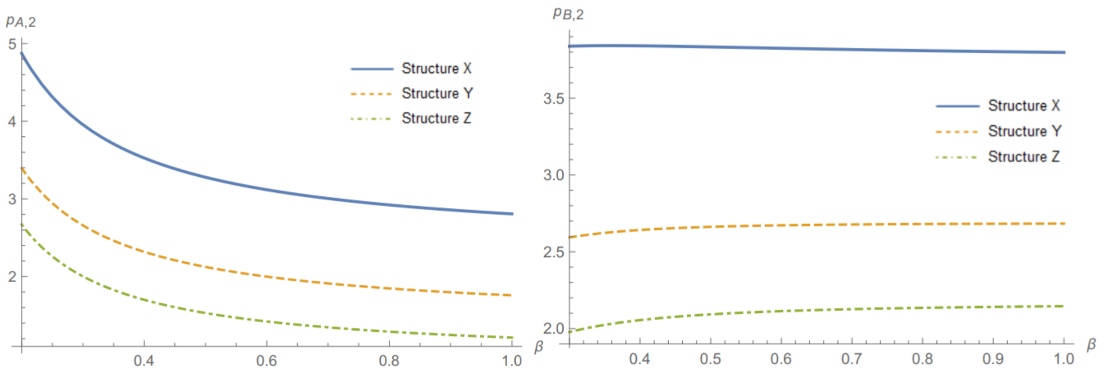

Figure 7 Firm A and B's Retail Prices in Period 2

Then, we study firms' pricing decisions. Figure 7 illustrates their retail prices in period 2. We observe that, as the fraction of variety seeking customers increases, the firms both set lower retail prices in period 2. The result is similar to that in the basic model. Differently, as β increases, firm B has incentives to increase its retail price because its rival's quality improvement cost is high and firm B's price flexibility/space becomes large.

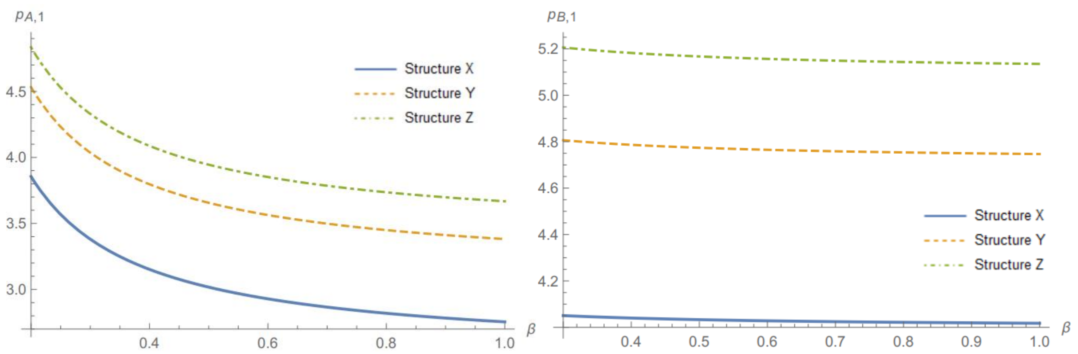

Figure 8 Firm A and B's Retail Prices in Period 1

Figure 8 illustrates firms' retail prices in period 1. We have used the competition mitigation effect and the production cost reduction effect to explain the results in Proposition 2. We conclude that $p_{i,1}^X < p_{i,1}^Y < p_{i,1}^Z$ holds only when β is sufficiently large. Here we observe that, regardless of β's value, $p_{i,1}^X < p_{i,1}^Y < p_{i,1}^Z$ always holds. Note that, in our extended model, only firm A has quality decision. Therefore, the competition mitigation effect is enhanced while the production cost reduction effect is weakened. As a result, the competition mitigation effect always dominates the production cost reduction effect.

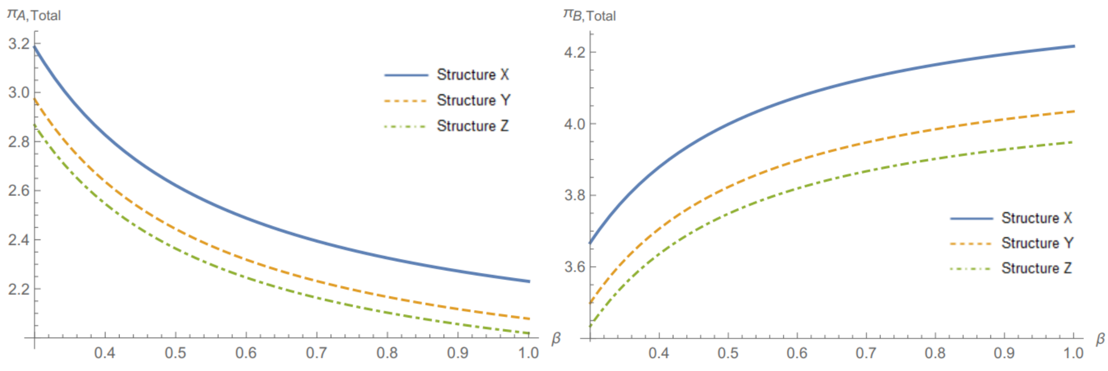

Figure 9 Firm A and B's Total Profits

Finally, we observe from Figure 9 that, the variety seeking customers have a negative impact on firms' profits. This observation is consistent with the empirical results in Woratschek and Horbel (2006).

6 Conclusion

In the recent years, more and more customers are willing to try new products by showing that they are in a new generation. Consequently, when they purchase products, they do not want to purchase the same one again and become "variety seeking customers". Being aware of this, firms have made efforts to manage variety seeking customers, so as to enlarge demand and increase profit gains. Previous studies have suggested price weapon, however, price is not powerful enough. In this paper we study two weapons' joint impacts by building a two period model involving price and quality decisions. We use Hotelling model to formulate customers' product choice and the demand reallocation because of the existence of variety seeking customers. We focus on three market structures: (1) Structure X (full of regular customers); (2) Structure Y (mix market of regular and variety seeking customers); (3) Structure Z (full of variety seeking customers). We are interested in the firms' decisions of price, quality level, and the resulted customer surplus. Quality improvement cost is assumed to be effort-dependent.

Our findings are three-folded. First, we show that the competition is mitigated in period 1 while intensified in period 2 due to the customers' variety seeking behavior. Second, we study the firm's price and quality level decisions. We show that, the existence of the variety seeking consumers leads to a lower quality level and retail price in period 2. The impact of variety seeking customers on period 1's retail price depends on the effort cost coefficient. We also show that, the firms' profits are worse off in the mixed market Y when the effort cost coefficient is small. Finally, from the perspective of customer surplus, regular and variety seeking customers can reach a win-win situation when the effort cost coefficient is in a moderate range.

These findings can be insightful. For example, traditional automobile firms such as Toyota, Honda and Ford are suggested to set a high markup in the first selling season but a low markup in the second selling season, because Chinese customers are usually variety seeking, which intensifies the traditional automobile firms' market competition with China local brands (e.g., Great Wall, Geely, BYD and Chery). Fashion brands such as H&M, Uniqlo, Zara should be more cautious about investing in quality, because the fraction of variety seeking customers is large and the customers' tastes change rapidly. We also suggest Chinese firms to improve quality investment efficiency when its rival imports overseas products, because the resulted quality level might be higher than the imported products', given a small effort cost coefficient.

We discuss two future research directions to conclude this paper. We have assumed that the two firms are identical for model tractability. In practice, firms can adjust the location of their products to change product differentiation. That will incur additional costs and make the joint price and quality decisions more complicated. Second, we have omitted loyal customers who will not change their products even if their net utilities in period 2 are negative. The loyal customers will help firms to increase the price in period 2 and lower that in period 1. The quality level might be increased because firms are encouraged to snatch more customers in period 1. However, that is beyond the scope of this paper.

Acknowledgements

The authors are grateful to the editors and reviewers for their helpful comments. The first author's work was supported by NSFC Excellent Young Scientists Fund (No. 71822202), NSFC (No. 71571194, 71472191), Chang Jiang Scholars Program (Niu Baozhuang 2017), GDUPS (Niu Baozhuang 2017). Lei Chen is the co-first author, whose work was supported by the Joint Supervision Scheme with the Chinese Mainland, Taiwan and Macao Universities from HKPolyU and RGC of the Hong Kong Special Administrative Region, China (No. G-SB0T). Yaoqi Liu is the corresponding author. The fourth author's work was supported by Central Research Grant, PolyU (No. G-YBZV).

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Appendix

Proof of Lemma 4

Lemma 4 can be derived by comparing the profit margins among three structures, respectively. The comparison results in period 2 are:

$$p_{i,2}^X - \alpha v_{i,2}^X - \left(p_{i,2}^Y - \alpha v_{i,2}^Y\right) = \frac{m\theta}{1+\theta} > 0;$$

$$p_{i,2}^X - \alpha v_{i,2}^X - \left(p_{i,2}^Z - \alpha v_{i,2}^Z\right) = \frac{m}{2} > 0;$$

$$p_{i,2}^Y - \alpha v_{i,2}^Y - \left(p_{i,2}^Z - \alpha v_{i,2}^Z\right) = \frac{m(1-\theta)}{2(1+\theta)} > 0.$$

The comparison results in period 1 are:

$$p_{i,1}^X - \alpha v_{i,1}^X - \left(p_{i,1}^Y - \alpha v_{i,1}^Y\right) = -\frac{2m\theta}{3(1+\theta)} < 0;$$

$$p_{i,1}^X - \alpha v_{i,1}^X - \left(p_{i,1}^Z - \alpha v_{i,1}^Z\right) = -\frac{m}{3} < 0;$$

$$p_{i,1}^Y - \alpha v_{i,1}^Y - \left(p_{i,1}^Z - \alpha v_{i,1}^Z\right) = -\frac{m(1-\theta)}{3(1+\theta)} < 0.$$

Proof of Proposition 1

Comparing the quality levels in these three structures, we have,

$$v_i^X - v_i^Y = \frac{(1-\alpha)\theta(3+2\theta)}{3\beta(27+27\theta-4\theta^2)} > 0;$$

$$v_i^X - v_i^Z = \frac{1-\alpha}{30\beta} > 0;$$

$$v_i^Y - v_i^Z = \frac{(1-\alpha)(1-\theta)(9+8\theta)}{10\beta(27+27\theta-4\theta^2)} > 0.$$

Proof of Proposition 2

First, we compare the retail prices in period 2:

$$p_{i,2}^X - p_{i,2}^Y = \frac{\theta[(1-\alpha)\alpha(1+\theta)(3+2\theta)+3m(27+27\theta-4\theta^2)\beta]}{3\beta(1+\theta)(27+27\theta-4\theta^2)} > 0;$$

$$p_{i,2}^X - p_{i,2}^Z = \frac{(1-\alpha)\alpha+15m\beta}{30\beta} > 0;$$

$$p_{i,2}^Y - p_{i,2}^Z = \frac{(1-\theta)[(1-\alpha)\alpha(1+\theta)(9+8\theta)+5m(27+27\theta-4\theta^2)\beta]}{10\beta(1+\theta)(27+27\theta-4\theta^2)} > 0.$$

Then, we focus on the retail prices in period 1. Solving $p_{i,1}^X - p_{i,1}^Y = 0$, we have $\beta = \frac{(1-\alpha)\alpha(1+\theta)(3+2\theta)}{2m(27+27\theta-4\theta^2)}$. When $\beta < \frac{(1-\alpha)\alpha(1+\theta)(3+2\theta)}{2m(27+27\theta-4\theta^2)}$, we have $p_{i,1}^X - p_{i,1}^Y > 0$. Similarly, when $\beta < \frac{(1-\alpha)\alpha}{10m}$, we have $p_{i,1}^X - p_{i,1}^Z > 0$; When $\beta < \frac{3(1-\alpha)\alpha(1+\theta)(9+8\theta)}{10m(27+27\theta-4\theta^2)}$, we have $p_{i,1}^Y - p_{i,1}^Z > 0$. We further compare three thresholds as follows. Let $\beta_1 = \frac{(1-\alpha)\alpha(1+\theta)(3+2\theta)}{2m(27+27\theta-4\theta^2)}$, $\beta_2 = \frac{(1-\alpha)\alpha}{10m}$, $\beta_3 = \frac{3(1-\alpha)\alpha(1+\theta)(9+8\theta)}{10m(27+27\theta-4\theta^2)}$. It can be verifies that

$$\beta_1 - \beta_2 = -\frac{(1-\alpha)\alpha(1-\theta)(6+7\theta)}{5m(27+27\theta-4\theta^2)} < 0;$$

$$\beta_2 - \beta_3 = -\frac{2(1-\alpha)\alpha\theta(6+7\theta)}{5m(27+27\theta-4\theta^2)} < 0.$$

Proof of Proposition 3

$$\pi_{i,Total}^{X} - \pi_{i,Total}^{Y} = -\frac{\theta[(1-\alpha)^2(1+\theta)(3+2\theta)(36+35\theta-6\theta^2) - m(27+27\theta-4\theta^2)^2\beta]}{6\beta(1+\theta)(27+27\theta-4\theta^2)^2}$$

$$\pi_{i,Total}^{X} - \pi_{i,Total}^{Z} = -\frac{13(1-\alpha)^2 - 50m\beta}{600\beta} > 0$$

$$\pi_{i,Total}^{Y} - \pi_{i,Total}^{Z} = -\frac{(1-\theta)[(1-\alpha)^2(1+\theta)(9+8\theta)(1053+1023\theta-176\theta^2) - 50m(27+27\theta-4\theta^2)^2\beta]}{600\beta(1+\theta)(27+27\theta-4\theta^2)^2}$$

$$\pi_{i,Total}^{Y} - \pi_{i,Total}^{Z} > 0 \Leftrightarrow \beta > \frac{(1-\alpha)^2(1+\theta)(9+8\theta)(1053+1023\theta-176\theta^2)}{50m(27+27\theta-4\theta^2)^2} = \beta_4$$

Proof of Proposition 4

$$CS_{R,1}^{X} - CS_{R,1}^{Y} = \frac{\theta[(1-\alpha)^2(1+\theta)(3+2\theta) + 2m(27+27\theta-4\theta^2)\beta]}{3\beta(1+\theta)(27+27\theta-4\theta^2)} > 0$$

$$CS_{R,2}^{X} - CS_{R,2}^{Y} = \frac{\theta[(1-\alpha)^2(1+\theta)(3+2\theta) - 3m(27+27\theta-4\theta^2)\beta]}{3\beta(1+\theta)(27+27\theta-4\theta^2)} < 0$$

$$CS_{R,Total}^{X} - CS_{R,Total}^{Y} = \frac{\theta[2(1-\alpha)^2(1+\theta)(3+2\theta) - m(27+27\theta-4\theta^2)\beta]}{3\beta(1+\theta)(27+27\theta-4\theta^2)}$$

$$CS_{R,Total}^{X} - CS_{R,Total}^{Y} > 0 \Leftrightarrow \beta < \frac{2(1-\alpha)^2(1+\theta)(3+2\theta)}{m(27+27\theta-4\theta^2)} = \beta_5$$

Proof of Proposition 5

$$CS_{S,1}^{Y} - CS_{S,1}^{Z} = \frac{(1-\theta)[3(1-\alpha)^2(1+\theta)(9+8\theta) + 10m(27+27\theta-4\theta^2)\beta]}{30\beta(1+\theta)(27+27\theta-4\theta^2)} > 0$$

$$CS_{S,2}^{Y} - CS_{S,2}^{Z} = \frac{(1-\theta)[(1-\alpha)^2(1+\theta)(9+8\theta) - 5m(27+27\theta-4\theta^2)\beta]}{10\beta(1+\theta)(27+27\theta-4\theta^2)} < 0$$

$$CS_{S,Total}^{Y} - CS_{S,Total}^{Z} = \frac{\theta[6(1-\alpha)^2(1+\theta)(9+8\theta) - 5m(27+27\theta-4\theta^2)\beta]}{30\beta(1+\theta)(27+27\theta-4\theta^2)}$$

$$CS_{S,Total}^{Y} - CS_{S,Total}^{Z} > 0 \Leftrightarrow \beta < \frac{6(1-\alpha)^2(1+\theta)(9+8\theta)}{5m(27+27\theta-4\theta^2)} = \beta_6$$