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The Impact of Return Freight Insurance on Retailer's Choice of Refund Guarantee in the Presence of Private Brand

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ABSTRACT

Based on the introduction of private brands by retailers, this paper studies the effect of return compensation on retailer's optimal pricing. The results show that: (1) consumer return cost is lower than retailer return cost: low return compensation makes retailers give up providing refund guarantee for their own brands. Generally, compensation for returned goods shall be determined according to the specific situation of returned goods cost of each member of the supply chain. When return compensation is large, the retailer should choose to provide return compensation only for its own brand. (2) Consumer return cost is higher than retailer return cost: when the return cost is smaller or larger, retailer provides refund guarantee for its own brand. When return compensation is common and consumer return costs are low, retailers offering return compensation for private brands can have a negative impact.

***Keywords*：** *Private brand; Money-back guarantee; Pricing strategy*

1. INTRODUCTION

In recent years, a growing number of retailers have taken a new path to growth by building their own brands, such as Wal-mart's Wyi. With the development of the Internet, online shopping has become the main way of consumption, with China's online retail sales reaching 9.19 trillion yuan in the first three quarters of 2021, up 18.5 percent year-on-year, according to China's Ministry of Commerce. The rapid development of e-commerce has pushed retailers to develop online businesses, such as Taobao Xinxuan. As consumers are unable to touch the physical objects, the possibility of products not meeting consumers' expectations exists. In response, retailers are considering introducing refund policies that allow consumers to return unsatisfied products. Product return will produce return cost, in order to reduce the negative impact of return cost to consumers, many retailers buy freight insurance for consumers that is return compensation. Freight insurance has become very common on Tmall. On the one hand, the return compensation has attracted more consumers to buy products. But on the other hand, it also makes more consumers abuse the right to return goods, resulting in the loss of retailers' profits. Therefore, after the retailer introduces its own brand, how the return compensation affects the retailer's profit and how the retailer makes the refund policy has become a problem to be studied.

As for private brands, Sun Yongbo [1] analyzed the influencing factors of online retail private brand purchase intention. Liu Zhijie [2] believe that Internet private brands should be built from the aspects of accurate positioning, improving product quality and strengthening marketing. Duan Yongrui [3] studied the influence of reference price and quality perception on private brand pricing. Cheng[4]shows that the introduction of private brands is beneficial to all members of the supply chain. Al-monawer [5] considered the influence of consumer base on the quality and pricing of retailers' private brands. Zhang[6] studied whether retailers introduce high-end private brands or economical private brands to cope with manufacturer invasion. Liao[7] studied the quality positioning of retailers' private brands under different purchasing channels and the interaction with retailers' pricing.

The existing literature mainly studies the influence of refund guarantee on retailers and how retailers choose refund guarantee. Li Shumei [8] studied the influence of refund guarantee on retailers' optimal pricing, consumer surplus and social welfare. Huang Fu [9] analyzed the effects of refund guarantee and different decision sequences on the equilibrium results and manufacturers' opening of dual channels. Jin Liang [10] believe that brand differentiation competition is always beneficial to retailers, but its impact on high-end brand manufacturers is uncertain. Huang[11, 12] shows that the existence of money-back guarantee is beneficial to retailers but disadvantageous to manufacturers. Assarzadegan[13] 's results show that retailers' money-back guarantee for defective products is beneficial to all parties in the supply chain. Desmet [14] discussed the influence of refund guarantee on private brands and manufacturers' brand preference. At present, there is little research on freight insurance. Yang Lei [15] introduced freight insurance into the newsboy model to discuss the change of income of all parties in the supply chain under the condition of the change of return rate. Hu Zhenhua [16] showed that the optimal strategy was not affected by the insurance buyers after the introduction of freight insurance.

2. PROBLEM DESCRIPTION AND MODEL ASSUMPTIONS

Suppose there is a manufacturer and a retailer in the market, and the retailer introduces its own brand to compete with the manufacturer's brand. In the event of a return, the retailer's own brand will be returned to the retailer and the manufacturer's brand will be returned to the retailer and then to the manufacturer through the retailer. To attract consumers, retailers are offering refund shipping costs.

In this paper, NB (National Brand) represents the manufacturer's Brand, SB (Store Brand) represents its own Brand, N and G respectively represent the situation where no or no money back guarantee is provided. Retailers have four refund policies, which are :(1) only private brands provide a refund guarantee (NG); (2) Only the manufacturer brand provides a money back guarantee (GN); (3) Both products provide a money back guarantee (GG); (4) Neither product offers a money back guarantee (NN). The retailer has four refund policies $K=\{NN,GN,NG,GG\}$.

Before receiving the goods, consumers can not determine whether the quality meets the requirements. Use $\theta_i(i=n,s)$ to represent the probability that the product meets consumer needs and $0<\theta_i<1$ assume $\theta_n>\theta_s$ .When the product meets consumer demand, consumers can obtain utility v_i-p_i, which v_i represents the uniform distribution of consumers' valuation of the product. Consumers have to pay the return t cost when they return goods. Therefore, if the retailer does not provide refund policy, the utility function obtained by consumers is: $U_i^N=\theta_i v-p_i$ When the retailer provides a refund policy, the utility function obtained by the consumer is: $U_i^G=\theta_i(v-p_i)-(1-\theta_i)(t-r)$, in order to conform to the actual situation, assume $r<t$. Consumers will buy NB products only when $U_n^K>0$ and $U_n^K>U_s^K$, otherwise, they will buy SB products, where v_s^K means there is no difference between buying SB products and not buying any products, v_n^K means there is no difference between buying NB products and buying SB products. Therefore, the demand function of the two products can be expressed as $q_n^K=1-v_n^K;q_s^K=v_n^K-v_s^K$.

Retailers and manufacturers incur return costs when consumers return goods. h_r and h_m represents the cost of returns to retailers and manufacturers. Based on the existing literature, it is assumed that the production cost of the product is 0.

3. MODEL

This part will solve the game equilibrium of the four situations, and the decision order is (1) the retailer decides the way of consumer return; (2) Manufacturers determine the wholesale price; (3) The retailer decides the demand for the product; (4) Consumers decide which products to buy.

3.1 Model NN

Neither product offers a refund policy and The profit function of retailer and manufacturer is:

$$\max_{w_n}\Pi_M^{NN}=q_nw_n\text{ ; }\max_{q_n、q_s}\Pi_R^{NN}=(p_n-w_n)q_n+p_sq_s \quad (1)$$

3.2 Model GN

Retailers only offers a refund policy for NB products. The profit function of retailer and manufacturer is:

$$\max_{w_n}\Pi_M^{GN}=\theta_nq_nw_n-h_m(1-\theta_n)q_n\text{ ;}$$
$$\max_{q_n,q_s}\Pi_R^{GN}=\theta_n(p_n-w_n)q_n-(1-\theta_n)h_rq_n+p_sq_s \quad (2)$$

3.3 Model NG

Retailers only offers a refund policy for SB products. The profit function of retailer and manufacturer is:

$$\max_{w_n}\Pi_M^{NG}=q_nw_n\text{ ;}$$
$$\max_{q_n,q_s}\Pi_R^{NG}=(p_n-w_n)q_n+\theta_sp_sq_s-(1-\theta_s)h_rq_s \quad (3)$$

3.4 Model GG

If the retailer provides a refund guarantee for the two products, the profit function of the retailer and the manufacturer is:

$$\max_{w_n}\Pi_M^{GG}=\theta_nq_nw_n-h_m(1-\theta_n)q_n\text{ ;}$$
$$\max_{q_n、q_s}\Pi_R^{GG}=\theta_n(p_n-w_n)q_n-(1-\theta_n)h_rq_n+\theta_sp_sq_s-(1-\theta_s)h_rq_s \quad (4)$$

The final equilibrium solution and the optimal profit obtained are shown in Table 1 and Table 2.

Table 1. The equilibrium

	NN	GN	NG	GG
w_n^*	$\frac{\theta_n-\theta_s}{2}$	$\frac{t-h_r(1-\theta_n)+(r-t)\theta_n-\theta_s-r}{2\theta_n}$	$\frac{r-t+h_r+\theta_n-(1+r-t+h_r)\theta_s}{2}$	$\frac{h_m+(1+r-t-h_m+h_r)\theta_n+(t-h_r-1-r)\theta_s}{2\theta_n}$
q_n^*	$\frac{1}{4}$	$\frac{t-h_r(1-\theta_n)+(2+r-t)\theta_n-\theta_s-r}{4(\theta_n-\theta_s)}$	$\frac{r-t+h_r+\theta_n+(t-h_r-1-r)\theta_s}{4(\theta_n-\theta_s)}$	$\frac{(1+r-t+h_m+h_r)\theta_n+(t-h_r-1-r)\theta_s-h_m}{4(\theta_n-\theta_s)}$
q_s^*	$\frac{1}{4}$	$\frac{r-t+h_r(1-\theta_n)-(r-t)\theta_n-\theta_s}{4(\theta_n-\theta_s)}$	$\frac{(r-t+h_r)\theta_s-(1+r-t+h_r)\theta_s^2+\theta_n[2(t-h_r-r)+(1+2r-2t+2h_r)\theta_s]}{4(\theta_n-\theta_s)\theta_s}$	$\frac{(2r-2t+h_m+2h_r)\theta_s-(1+r-t+h_r)\theta_s^2-\theta_n[2(r-t+h_r)+(t+h_m-h_r-1-r)\theta_s]}{4\theta_s(\theta_n-\theta_s)}$
p_n^*	$\frac{3\theta_n-\theta_s}{4}$	$\frac{3(t-r)+h_r(1-\theta_n)+(2+3r-3t)\theta_n}{4\theta_n}$	$\frac{r-t+h_r+3\theta_n-(1+r-t+h_r)\theta_s}{4}$	$\frac{2(t+h_r-r)+h_m+[3(1+r-t)-h_m-h_r]\theta_n+(t-h_r)\theta_s}{4\theta_n}$
p_s^*	$\frac{\theta_s}{2}$	$\frac{\theta_s}{2}$	$\frac{t+h_r(1-\theta_s)+(1+r-t)\theta_s-r}{2\theta_s}$	$\frac{t-r+h_r(1-\theta_s)+(1+r-t)\theta_s}{2\theta_s}$

Table 2. The optimal profit

	π_R^*	π_M^*
NN	$\frac{1}{16}(\theta_n+3\theta_s)$	$\frac{1}{8}(\theta_n-\theta_s)$
GN	$\frac{(r-t)^2+h_r^2(1-\theta_n)^2+(2+r-t)^2\theta_n^2-2h_r(1-\theta_n)[t+(2+r-t)\theta_n-\theta_s-r]+\theta_s[2(r-t)-3\theta_s]-2(r-t)(2+r-t+\theta_s)\theta_n}{16(\theta_n-\theta_s)}$	$\frac{[t-h_r(\theta_n-1)+(2+r-t)\theta_n-\theta_s-r][t-2h_m-h_r-r(1-\theta_n)+(2h_m+h_r-t)\theta_n-\theta_s]}{8(\theta_n-\theta_s)}$
NG	$\frac{\theta_s\left\{\theta_n^2-3[t-h_r(1-\theta_s)+(1+r-t)\theta_s-r]^2\right\}+2\theta_n\left\{\begin{matrix}2(r-t)^2+2h_r^2(1-\theta_s)^2+\theta_s[(3-4t)t-r(3-8t-4r)]+\\ \theta_s^2[1+r(2r+3-4t)-t(2t-3)]-h_r(1-\theta_s)[4t-4r+(3+4r-4t)\theta_s]\end{matrix}\right\}}{16\theta_s(\theta_n-\theta_s)}$	$\frac{[t-r-h_r-\theta_n+(1+r-t+h_r)\theta_s]^2}{8(\theta_n-\theta_s)}$
GG	$\frac{\theta_s[4(t^2-r^2)+h_m^2-4h_r(2r+h_r)+8t(r+h_r)]+(1+r-t+h_m+h_r)^2\theta_n^2\theta_s+2\theta_s^2[4r(r+1-2t)-4t(1-t)+4h_r(1+2r-2t+h_r)+h_m(1+r-t+h_r)]+3\theta_s^3[2r(t-h_r-1)+2t(1+h_r)-h_r(2+h_r)-r^2-t^2-1]+4[(r-t)^2+2(r-t)h_r+h_r^2]}{16(\theta_n-\theta_s)\theta_s}$	$\frac{[(1+r-t+h_r)(\theta_n-\theta_s)-h_m(1-\theta_n)]^2}{8(\theta_n-\theta_s)}$

4. ANALYSIS OF FINAL GAME RESULTS

4.1 Retailer money back guarantee policy

Firstly, NG and NN is taken as the benchmark case, and the retailer profits of the two cases are compared to obtain proposition 1.

proposition 1: (1) The return cost of consumers is higher than that of retailers: the freight compensation in $0<r<r_1$, retailers only provide a refund guarantee for SB products; in $r_1<r<r_2$ the retailer does not give a money-back guarantee on any product; in $r>r_2$, the retailer only gives SB a money-back guarantee for its products. (2) The cost of returning goods to the consumer is lower than the cost of returning goods to the retailer: when the retailer's cost of returning goods is lower, in $0<r<r_2$, Neither product comes with a money-back guarantee; in $r>r_2$ only SB products offer a money-back guarantee; When the retailer's return costs are high, the retailer only offers a money-back guarantee for SB products.

When the return cost of consumers is higher than that of retailers, on the one hand, the market share of SB products is smaller than that of NB products. On the other hand, the offer of a money-back guarantee increases SB's cost of selling its products. But the increase in SB's prices was not enough to compensate for its lack of market share. When the return cost of consumers is lower than the return cost of retailers, retailers provide higher freight compensation, which will attract consumers to buy products, and retailers can charge higher prices to make up for the loss of less market share. Therefore, retailers can provide refund guarantee for SB products.

If in proposition 1 the retailer decides to NG, on the basis of proposition 1, the retailer's profits under the two scenarios NG and GG are compared and the retailer's optimal strategy is finally obtained.

Proposition 2: (1) The return cost of consumers is higher than that of retailers:in addition to $\frac{h_m(\theta_n-1)+(\theta_n-\theta_s)}{1+\theta_n-2\theta_s}<t<h_m$, $h_m<\frac{\theta_s-\theta_n}{\theta_s-1}$ and $0<r<r_1$ or $\frac{h_m(\theta_n-1)+(\theta_n-\theta_s)}{1+\theta_n-2\theta_s}<t<h_m$, $h_m>\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$ and $r_2<r<r_4$

The retailer offers a money back guarantee for both products, whereas the retailer only offers a money back guarantee for SB products .(2)The cost of returning goods to consumers is lower than that to retailers:

In most cases retailers choose to only give SB a money back guarantee on their products, however in $0<t<h_r<\frac{t-h_m(-1+\theta_n)+(-2+t)\theta_n+2\theta_s-2t\theta_s}{1+\theta_n-2\theta_s}$, $h_m>\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$ and $r_2<r<r_4$, both products offer money-back guarantees to the benefit of retailers.

When manufacturers and retailers have low return costs, return compensation can entice consumers to buy products. If the cost of returning goods is high, the manufacturer will increase the wholesale price to make up for the loss of profits.,the higher selling price will lead to the decrease of the purchase rate. Similarly, the purchase of freight insurance adds to the retailer's costs. In order to achieve a win-win situation for the retailer and the manufacturer, the retailer should provide a money-back guarantee for both products within appropriate freight reimbursement.

If the retailer chooses NN, then the retailer's profits in case NN and case GN are compared on the basis of proposition 5, and the retailer's optimal strategy is finally obtained.

Proposition 3: (1) The return cost of consumers is higher than that of retailers: freight compensation in $r_1<r<r_5$, retailer decided to offer a money-back guarantee for NB products;in $r_5<r<r_2$ retailer do not give money-back guarantees on any products.(2)The cost of returning goods to consumers is lower than that to retailers: Retailers decided to offer a money-back guarantee for NB products when their return costs were low. When the retailer's return costs are higher in $0<r<r_5$ retailer decided to offer a money-back guarantee for NBs, in $r_5<r<r_2$ retailers should not give money-back guarantees for products.

The higher the return rate is, the higher the refund compensation will be. Therefore, if return compensation is high, the retailer benefits from not offering a money-back guarantee on either product. When freight compensation is low, the cost of sales can be controlled within the range that retailers can afford. Therefore, the provision of NB product refund guarantee is beneficial to retailers. If the return cost of consumers is lower than the return cost of retailers and the return cost of retailers is moderate, the provision of refund guarantee for NB products will increase the sales price of retailers. Retailers need to consider all types of consumers, so retailers should not provide refund guarantee for NB products.

4.2 Final equilibrium result

Table 3. When $t>h_r$ market equilibrium

t	h_m	r	The optimal strategy
$0<t<\frac{(1+h_m)(\theta_n-\theta_s)}{1+\theta_n-2\theta_s}$	$0<h_m<\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0<r<r_1$	NG
		$r_1<r<r_5$	GN
		$r_5<r<r_2$	NN
		$r>r_2$	NG
	$h_m>\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0<r<r_1$	GG
		$r_1<r<r_5$	GN
		$r_5<r<r_2$	NN
		$r>r_2$	NG
$\frac{h_m(\theta_n-1)+(\theta_n-\theta_s)}{1+\theta_n-2\theta_s}<t<h_m$	$0<h_m<\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$r>0$	NG
	$h_m>\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$		GG
$t>h_m$	$h_m>0$	$r>0$	NG

Table 4. When $t<h_r$ market equilibrium

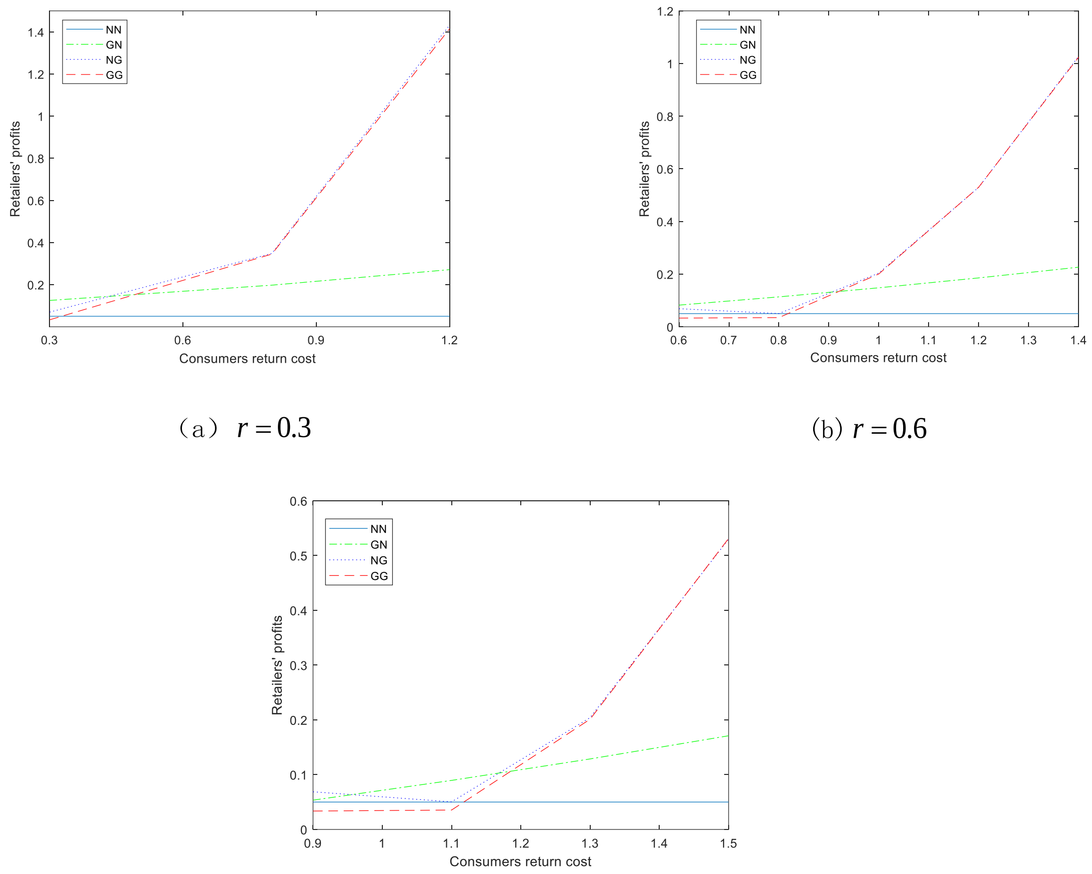
• t	h_m	r	The optimal strategy
$t<h_r<\frac{t\theta_n-t-\theta_n}{\theta_n-1}$	$0<h_m<\frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0<r<r_5$	GN
		$r_5<r<r_2$	NN
		$r_2<r$	NG
		$0<r<r_5$	GN

$\frac{t\theta_n - t - \theta_n}{\theta_n - 1} < h_r < \frac{(t-3)\theta_n + 2\theta_s - t}{\theta_n - 1}$	$h_m > \frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$r_5 < r < r_2$	NN
		$r_2 < r < r_4$	GG
		$r_4 < r$	NG
	$0 < h_m < \frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0 < r < r_2$	NN
		$r_2 < r$	NG
	$h_m > \frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0 < r < r_2$	NN
		$r_2 < r < r_4$	GG
		$r_4 < r$	NG
$h_r > \frac{(t-3)\theta_n + 2\theta_s - t}{\theta_n - 1}$	$0 < h_m < \frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0 < r < r_2$	GN
		$r_2 < r$	NG
	$h_m > \frac{2\theta_n^2(4-\theta_s)+6\theta_s^3-4\theta_n\theta_s(2+\theta_s)}{(1-\theta_n)(4\theta_n-3\theta_s)(1-\theta_s)}$	$0 < r < r_2$	GN
		$r_2 < r < r_4$	GG
		$r_4 < r$	NG

$r_2 = \frac{3\theta_s[t - h_r(1-\theta_s) + (2-t)\theta_s] + 2\theta_n[2h_r(1-\theta_s) + (2t-3)\theta_s - 2t]}{(4\theta_n - 3\theta_s)(\theta_s - 1)}$; $r_4 = \frac{t + h_m(1-\theta_n) + \theta_n(t-2) - h_r(1+\theta_n-2\theta_s) + 2\theta_s(1-t)}{1+\theta_n-2\theta_s}$; $r_5 = \frac{t + h_r(-1+\theta_n) - (-1+t)\theta_n}{1-\theta_n}$

5. NUMERICAL ANALYSIS

Parameter Settings are as follows: $\theta_n = 0.5, \theta_s = 0.1, h_m = 0.3, h_r = 0.2$,Choose $r = 0.3, r = 0.6, r = 0.9$ to represent small, moderate and large cases respectively.



(a) $r = 0.3$

(b) $r = 0.6$

(c) $r = 0.9$

Figure 1 The impact of consumer return costs on retailer profits

By observing figure 1 (a), we can see that when $t = r = 0.3$, curve GN is at the top, and it is beneficial for retailers to provide refund guarantee only for NB products. Curves GG and NG have an obvious upward trend at $t \to 0.8$, and the two curves basically coincide, indicating that retailers should choose to provide refund guarantee for SB products when the return cost of consumers is high.

In figure 1 (b). With the increase of t, curves GG and NG decrease slightly at first and increase greatly after $t > 0.8$. When t is small, curve GN is at the top; When t is large, curves GG and NG basically coincide and are located at the top, which indicates that the return compensation is generally the same as the result when the return compensation is small.

Figure 1 (c) shows that when $t = r = 0.9$, curve NG is at the top, which indicates that retailers should only provide refund guarantee for SB products when return compensation and consumer return cost are basically the same. When t is average, retailer's profit is the highest in GN. When t is large, curve NG is at the top. This means that when the return compensation is large and the return cost to the consumer is small or large, it's beneficial for the retailer to choose to provide a refund guarantee only for SB products.

6. CONCLUSION

Based on retailers to introduce their own brands to study the effect of the return of the compensation for retailers decision-making. NB products compete with SB products in the market, retailers in order to ensure profits for four refund way: only NB products provide, only SB products provide, two products don't offer, two kinds of products at the same time. With the leadership of the manufacturer Stackelberg methods respectively to get four cases of equilibrium solution, and finally through the contrast analysis to retailers. Main conclusions are as follows: (1) When consumers return cost is higher than the retailer to return costs, many cases, the retailer choose SB products only provide refund guarantee, but in return of the compensation. (2) When consumers return cost is lower than the retailers to return costs, low enough allows retailers to give up the return of the compensation for SB products provide refund guarantee. This research only considers a single retailer in the market of the supply chain structure, however, there are multiple retailers competing in practical life, and the retailers.

APPENDIX:

The model NN equilibrium calculation

Demand function are obtained by the utility function $q_n^{NN} = 1 - \frac{p_n^{NN} - p_s^{NN}}{\theta_n - \theta_s}$ 、 $q_s^{NN} = \frac{p_n^{NN} - p_s^{NN}}{\theta_n - \theta_s} - \frac{p_s^{NN}}{\theta_s}$,So the inverse demand function is ： $p_n^{NN} = \theta_n - q_n^{NN}\theta_n - q_s^{NN}\theta_s$ 、 $p_s^{NN} = \theta_s - q_n^{NN}\theta_s - q_s^{NN}\theta_s$ .Make $\frac{\partial \Pi_R^{NN}}{\partial q_n^{NN}} = 0$, $\frac{\partial \Pi_R^{NN}}{\partial q_s^{NN}} = 0$ get Heessian matrix for: ： $H = \begin{vmatrix} -2\theta_n & -2\theta_s \\ -2\theta_s & -2\theta_s \end{vmatrix} = 4(\theta_n - \theta_s)\theta_s > 0$,the Hessian matrix is negative definite. Substitute the response functions into the objective function of the manufacturer, then the optimal decision of the manufacturer could be found by $\frac{\partial \Pi_M^{NN}}{\partial w_n^{NN}} = 0$ and the second order derivative can be calculated by $\frac{\partial^2 \Pi_M^{NN}}{\partial w_n^{NN^2}} = -\frac{1}{\theta_n - \theta_s} < 0$, since the second derivative is negative, it has a maximum. Take the optimal wholesale price into the response functions of the retailer could result in the equilibrium retail price of the retailer.only the calculation process of the equilibrium solution in the case is shown.

Proposition 1 proves: Comparison case NG and NN

$$\pi_R^{NG^*} - \pi_R^{NN^*} = \frac{(r-t+h_r)(\theta_s-1)\{2\theta_n[2t-2r+2h_r(\theta_s-1)+\theta_s(3+2r-2t)]+3\theta_s[r-t+h_r(1-\theta_s)-(2+r-t)\theta_s]\}}{16(\theta_n-\theta_s)\theta_s}$$

$$f_1(r) = (r-t+h_r)\{2\theta_n[2t-2r+2h_r(\theta_s-1)+\theta_s(3+2r-2t)]+3\theta_s[r-t+h_r(1-\theta_s)-(2+r-t)\theta_s]\}$$

$$f_1'(r) = 0 \Rightarrow r_1^* = \frac{3\theta_s[t-h_r(1-\theta_s)+(1-t)\theta_s]+\theta_n[4h_r(1-\theta_s)+(4t-3)\theta_s-4t]}{(4\theta_n-3\theta_s)(\theta_s-1)}$$

$$f_1(r) = 0 \Rightarrow \begin{cases} r_1 = t-h_r \\ r_2 = \frac{3\theta_s[t-h_r(1-\theta_s)+(2-t)\theta_s]+2\theta_n[2h_r(1-\theta_s)+(2t-3)\theta_s-2t]}{(4\theta_n-3\theta_s)(\theta_s-1)} \end{cases}$$

1.When $t > h_r$ the parabola intersects the horizontal axis twice r_1 and r_2 $\therefore 0 < r < r_1$, $f(r) < 0 \Rightarrow \pi_R^{NG*} > \pi_R^{NN*}$

$r_1 < r < r_2,\ f_1(r) > 0 \Rightarrow \pi_R^{NG^*} < \pi_R^{NN^*}$

$r > r_2,\ f_1(r) < 0 \Rightarrow \pi_R^{NG^*} > \pi_R^{NN^*}$

2.When $h_r > \frac{6\theta_s(\theta_n-\theta_s)}{(4\theta_n-3\theta_s)(1-\theta_s)}, 0 < t < h_r + \frac{6(\theta_n-\theta_s)\theta_s}{(4\theta_n-3\theta_s)(\theta_s-1)}$,

$f_1(0) < 0, r_1^* > 0 \therefore r > 0$, $f_1(r) < 0 \Rightarrow \pi_R^{NG^*} > \pi_R^{NN^*}$

The proof process of the other propositions is similar that proposition 1, so only the proposition 1 be shown.

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