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Price and retailer's service level decision in a supply chain under consumer returns

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Abstract: To investigate the optimal retail price and service level in a supply chain under consumer returns, a consumer returns model under the retailer's service provision is built. The optimal decision results and optimal profits are obtained in the vertical integration game and the manufacturer Stackelberg game, respectively. Through comparing the optimal profits with service provision with those of no service provision, the boundary conditions that the retailer's service should be provided are derived. The results show that in the manufacturer Stackelberg game, the optimal profit of the retailer and the manufacturer with service is always superior to that of a no service provision. However, in the vertical integration game, the supply chain can only benefit from the service under certain conditions. Finally, through numerical examples, the impacts of the cost for providing services and the consumer return rate on the optimal decisions are analyzed.

Key words: pricing decision; service level; consumer returns; Stackelberg game; vertical integration

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Many reasons can cause consumer returns, for example, product quality failures or product mismatch with consumer taste, etc. The flow of consumer returns brings serious profit losses for manufacturers and it has been frequently reported in recent years. According to Ref. [1], the US electronics industry spent about 13.8 billion dollars to re-box, restock and resell returned products in 2007. It is estimated that only about 5% of consumer returns are truly defective, and as much as 19% of the electronics purchases is returned to the store even though there is no defect.

Therefore, retailers take efforts to increase investment in services (e.g., greater shelf display to properly showcase the full set of models and sizes of the product, or more qualified sales staff) to reduce the likelihood of a product mismatch and hence a return. The key question is whether improving the service level will make a higher consumer demand and a lower consumer return rate; however, it will also increase the retailer's input cost. The objective of this paper is to build a consumer returns model and investigate how to trade off the cost and the profit resulting from the retailer's service. Furthermore, we introduce the questions: Can providing service be always beneficial for the retailer? How does the consumer return rate impact the optimal decisions?

Consumer returns has been viewed as an important policy and has received wide attention in academic literature. Consumer returns affect the decision-makers' price and order quantity decisions. Davis et al. [2] found that when the retailer had a sufficiently high salvage value, a money-back guarantee policy was more profitable than a no-refund policy. In Ref. [3], the refund amount was regarded as a decision variable and a profit-maximization model was developed to obtain optimal policies for price and the return policy in terms of certain market reaction parameters. However, in this paper, we assume that the refund amount is exogenously given, and we intend to reduce the consumer return rate and make profits optimal by providing the service. Chen and Bell[4] addressed the simultaneous determination of price and inventory replenishment when customers returned products to the firm. In addition, the supply chain coordination on consumer returns was investigated in Refs. [5 - 6].

The service provisions affect the decisions of the supply chain. Ernst and Powell[7] examined the impact of manufacturer's incentives on profits of the supply chain when the demand was a function of the service level. Wu[8] considered the optimal pricing and service level decisions in four channel strategies: vertical integration, vertical Nash, manufacturer's Stackelberg and retailer's Stackelberg. Xiao and Yang[9] discussed the supply chains with risk-averse retailers competing in price and service level, where the demand was seen as a linear function with the price and service levels. However, they could touch upon consumer returns.

Combining the consumer returns policy, Ferguson et al. [10] addressed the problem of reducing false failure returns via a target rebate contract to coordinate the supply chain. In their paper, they only investigated the optimal promotion level through viewing the retail price as an exogenous variable. However, in this paper, we treat the

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retail price as a decision variable, and the model demand as a linear function with the retail price and the service level. Furthermore, the aim of the service provisions mentioned in Refs. [7 - 10] is only to increase demand, while, besides that, the service in our context can also be used to reduce mismatches. Ofek et al. [11] investigated the interplay between retailers and consumers in multi-channel systems. Their objective was to explore how the introduction of an online channel affects the retailers' service level, the pricing strategy and profits. However, in this paper, we consider the optimal decisions of the manufacturer and the retailer in a supply chain under the vertical integration (VI) game and the manufacturer Stackelberg (MS) game. Our goal is to study the decision differences and how the service level affects the decisions of the supply chain in different games.

1 Model and Notations

In this paper, we examine a supply chain with a manufacturer and a retailer, where a retailer provides the products for consumers and simultaneously accepts consumer returns. The salvage value of the returned product is assumed to be zero at the end of the sales season, and the manufacturer's production cost is c. The manufacturer sets the wholesale price w for the retailer, and the retailer sells products to consumers at the retail price p. Also, the retailer accepts consumer returns and the refund amount r ($r<p$) is assumed to be exogenous. Meanwhile, the retailer can choose whether to provide service $\lambda(0<\lambda<1)$ to reduce consumer returns, where the explanation of service is mentioned before. We assume that the likelihood of a product mismatch (return) without physical inspection is x $(0<x<1)$. After the retailer offers the service, the return rate becomes $x(1-\lambda)$.

Let $p>w>c$. We assume that the market demand is a linear function at the retail price and the service level. A better service level is both helpful to improve the consumers' purchasing confidence and to increase the demand. So, the demand function is expressed as

$$D(p,\lambda)=a-p+t\lambda$$

where a denotes the primary demand, and t denotes the service sensitivity of the market demands. The demand sensitivity to retail price is normalized to one. Reasonably, we require $D>0$, so we have $a-p>0$.

Then, the retailer's profit is

$$\Pi_{\mathrm{R}}=[p-w-xr(1-\lambda)]D-\frac{1}{2}h\lambda^2$$

The above expression of Π_{R} suggests that only when $p-w-xr(1-\lambda)>0$, the retailer can make a positive expected profit. In the retailer's profit function, $h\lambda^2/2$ is the retailer's cost of providing the service, which also increases the service level. Specially, when $t=0$, the retailer only needs to trade off the decrease of consumer return mismatches and the increase in the cost caused by providing the service.

The manufacturer's profit is

$$\Pi_{\mathrm{M}}=(w-c)D$$

The total profit of the supply chain is

$$\Pi_{\mathrm{SC}}=(p-c-xr(1-\lambda))D-\frac{1}{2}h\lambda^2$$

The above expression of Π_{SC} suggests that only when $p-c-xr(1-\lambda)>0$, the expected channel profit is positive.

In the game, manufacturers decide the wholesale price w and retailers decide the retail price p and service level λ. Then, the optimal order quantity is determined according to D.

2 Optimal Price and Service Level Decisions

In this section, we further investigate the optimal decision in the VI game and the MS game, respectively.

2.1 VI game

We first examine the condition where the optimal decisions exist, and give Lemma 1 as follows.

Lemma 1 The supply chain's profit Π_{SC} in the VI game is concave in both p and λ if $2h>(t+xr)^2$.

Proof Let $\boldsymbol{H}$ denote a Hessian of Π_{SC}. Computation of the Hessian matrix leads to $\boldsymbol{H}=\begin{bmatrix}-2 & t-xr\\ t-xr & 2txr-h\end{bmatrix}$. The determinant of $\boldsymbol{H}$ is $\det(\boldsymbol{H})=2h-(t+xr)^2$. $\boldsymbol{H}$ is negatively definite if $\det(\boldsymbol{H})>0$. That is, $2h>(t+xr)^2$. Hence, Π_{SC} is joint concave in p and λ, and Lemma 1 holds.

Under the conditions of Lemma 1, we obtain the optimal decision results in the VI game as follows.

Proposition 1 The supply chain's optimal retail price and service level are

$$p_{\mathrm{VI}}^*=\frac{h(a+c+xr)-(t+xr)((a+t)xr+ct)}{2h-(t+xr)^2}$$

$$\lambda_{\mathrm{VI}}^*=\frac{(t+xr)(a-c-xr)}{2h-(t+xr)^2}$$

where $2h>(t+xr)(t+a-c)$ is required to satisfy the condition of $\lambda_{\mathrm{VI}}^*<1$.

According to Proposition 1, we have the optimal order quantity $D_{\mathrm{VI}}^*=\dfrac{h(a-c-xr)}{2h-(t+xr)^2}$, and the optimal supply chain profit is $\Pi_{\mathrm{SC}}^{\mathrm{VI}}=\dfrac{h(a-c-xr)^2}{2[2h-(t+xr)^2]}$.

2.2 MS game

Here, we consider the manufacturer's and the retailer's decision in the decentralized case. We assume that the manufacturer is the Stackelberg leader, and the retailer is the follower. The decision sequence is as follows: the manufacturer first sets the wholesale price, and then the retailer determines the retail price and service level. We solve the model backward.

After the manufacturer sets the wholesale price w, the retailer's reaction functions are

$$\lambda = \frac{(t+xr)(a-w-xr)}{2h-(t+xr)^2}$$

$$p = \frac{h(xr+w+a)-(t+xr)(xr(a+t)+tw)}{2h-(t+xr)^2}$$

Then, the order quantity $D = \frac{h(a-w-xr)}{2h-(t+xr)^2}$.

According to the retailer's behavior, the manufacturer's reaction function is

$$\Pi_{\mathrm{M}} = (w-c)D = (w-c)\frac{h(a-w-xr)}{2h-(t+xr)^2}$$

Taking the first-order conditions with respect to the wholesale price in Π_{M}, we obtain the optimal wholesale price $w_{\mathrm{MS}}^* = \frac{a+c-xr}{2}$. Therefore, we obtain the following proposition.

Proposition 2 In the MS game, the retailer's optimal decisions are

$$p_{\mathrm{MS}}^* = \frac{h(xr+c+3a)-(t+xr)[(t+2a)xr+(a+c)t]}{2[2h-(t+xr)^2]}$$

$$\lambda_{\mathrm{MS}}^* = \frac{(t+xr)(a-c-xr)}{2[2h-(t+xr)^2]}$$

where $h > \frac{1}{4}[(t+xr)(a-c+xr+2t)]$ is required to satisfy the condition of $\lambda_{\mathrm{MS}}^* < 1$.

Then, the optimal order quantity is $D_{\mathrm{MS}}^* = \frac{h(a-c-xr)}{2[2h-(t+xr)^2]}$.

The optimal profits of the retailer, the manufacturer and the whole supply chain are $\Pi_{\mathrm{R}}^{\mathrm{MS}} = \frac{h(c-a+xr)^2}{8[2h-(t+xr)^2]}$, $\Pi_{\mathrm{M}}^{\mathrm{MS}} = \frac{h(c-a+xr)^2}{4[2h-(t+xr)^2]}$ and $\Pi_{\mathrm{SC}}^{\mathrm{MS}} = \frac{3h(c-a+xr)^2}{8[2h-(t+xr)^2]}$, respectively.

Analyzing the above optimal results, we obtain the following conclusions:

1) Let $p_{\mathrm{VI}}^* - p_{\mathrm{MS}}^* = \frac{(t^2+xr\,t-h)(a-c-xr)}{2(2h-(xr+t)^2)}$. If $h \geqslant t^2 + xrt$, then we have $p_{\mathrm{VI}}^* \leqslant p_{\mathrm{MS}}^*$. Otherwise, if $\frac{1}{2}(t+xr)^2 < h < t(t+xr)$, then we have $p_{\mathrm{VI}}^* > p_{\mathrm{MS}}^*$. Furthermore, we have $\lambda_{\mathrm{VI}}^* > \lambda_{\mathrm{MS}}^*$ and $D_{\mathrm{VI}}^* > D_{\mathrm{MS}}^*$ which shows that the retailer in the VI game provides the higher service level and has more order quantity than that in the MS game.

2) The optimal retail price increases with the increase in manufacturer's cost c, but the service level and order quantity decrease with the increase in c. It suggests that when the manufacturer's cost increases, the retailer should raise the retail price and decrease the service level and order quantity.

From Propositions 1 and 2, we can also see that the optimal value seriously depends on the service cost parameter h. So, in the next section, we will further investigate in what cases the service cost parameter h makes the retailer benefit from providing services.

3 Analyses and Managerial Insights

Based on the previous model, let $\lambda = 0$ and then we obtain the optimal profits without the retailer's service in Tab. 1.

Tab. 1 Optimal analytical solutions without the retailer's service

Profit	VI game	MS game
Π_{R}		$\frac{(c-a+rx)^2}{16}$
Π_{M}		$\frac{(c-a+rx)^2}{8}$
Π_{SC}	$\frac{(a-c)^2-r^2x^2}{4}$	$\frac{3(c-a+rx)^2}{16}$

Through the comparison, we obtain Proposition 3 and Proposition 4.

Proposition 3 In the MS game, the optimal profits of both the retailer and the manufacturer with service are greater than those without it.

Proof Comparing the retailer's optimal profit with service in the MS game with that without service, we obtain that

$$\frac{h(c-a+xr)^2}{8[2h-(t+xr)^2]} - \frac{(c-a+rx)^2}{16} = \frac{(c-a+rx)^2}{8}\left(\frac{(t+xr)^2}{2[2h-(t+xr)^2]}\right) > 0$$

The other case can be proved by the similar way.

Proposition 4 In the VI game, the optimal profit of the supply chain with service is greater than that without service only if $\frac{1}{2}(t+xr)(t+a-c) < h < \frac{(a-c+xr)(t+xr)^2}{4rx}$.

Proof $\frac{h(a-c-xr)^2}{2[2h-(t+xr)^2]} - \frac{(a-c)^2-r^2x^2}{4} = \frac{(a-c-xr)}{2}\frac{[-4hxr+(a-c+xr)(t+xr)^2]}{2[2h-(t+xr)^2]}$. Next, we only need make the sign of $-4hxr+(a-c+xr)(t+xr)^2$. Therefore, if $h < \frac{(a-c+xr)(t+xr)^2}{4rx}$, then we say that the optimal profit of the supply chain with service in the VI game is greater than that without service. Simultaneously, combining the limitation condition of $h > \frac{1}{2}(t+xr)(t+a-c)$ in Proposition 1, we know that Proposition 4 holds.

4 Numerical Examples

In this section, we first analyze how the parameter h

impacts the optimal decision of the supply chain. Let $a = 10$, $r = 6$, $c = 1$, $t = 20$, $h = 350:10:500$ and $x = 0.5$.

From Fig. 1, we can see that when $p = 460$, the optimal retail price in the VI game is equal to that in the MS game. Meanwhile, when $p > 460$, the optimal retail price in the VI game is lower than that in the MS game, and conversely reverse. Furthermore, the optimal retail price in the VI game is more seriously affected by h than that in the MS game.

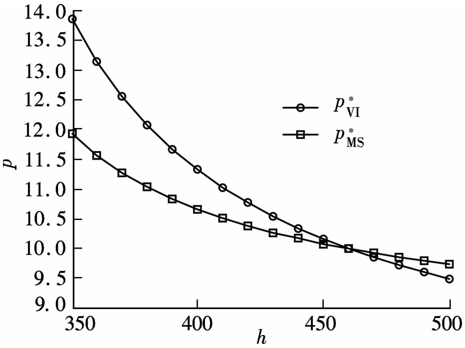

Fig. 1 The change of p with h

From Fig. 2, we can conclude that the optimal service level and its degree affected by h in the VI game are greater than those in the MS game. Then, we further analyze the impact of h on the profit in Fig. 3.

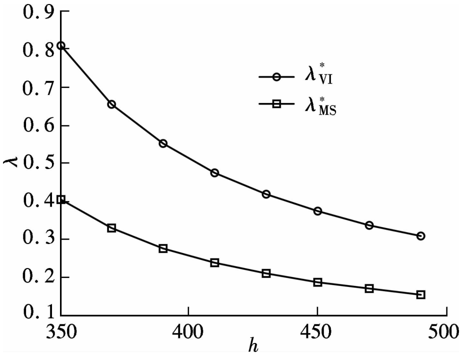

Fig. 2 The change of λ with h

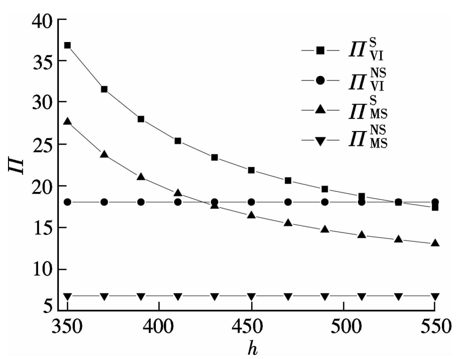

Fig. 3 The change of Π with h

From Fig. 3, we can summarize that when $h > 529$, the total profit of the supply chain with service is greater than that without service in the VI game, and conversely reverse. In addition, the total profit of the supply chain with service is always greater than that without service in the MS game.

In the case of service provision, the degree of the supply chain's profit affected by h in the VI game is slightly greater than that in the MS game.

5 Impact of Consumer Return Rate on Optimal Decisions

We first analyze how the consumer return rate impacts on the optimal decisions when $t = 0$. Then, the demand function becomes $D = a - p$. According to Propositions 3 and 4, we know that $\frac{1}{2}xr(a-c) < h < \frac{1}{4}xr(a-c+xr)$ holds. Based on this condition, we conclude Proposition 5 and Proposition 6 as follows.

Proposition 5 If $h > \frac{1}{2}rx(2a-2c-rx)$, then $\frac{dp^*_{VI}}{dx} > \frac{dp^*_{MS}}{dx} > 0$ and $\frac{dD^*_{VI}}{dx} < \frac{dD^*_{MS}}{dx} < 0$. Otherwise, if $\frac{1}{4}rx(a-c+rx) < h < \frac{1}{2}rx(2a-2c-rx)$, then $\frac{dp^*_{VI}}{dx} < \frac{dp^*_{MS}}{dx} < 0$ and $\frac{dD^*_{VI}}{dx} > \frac{dD^*_{MS}}{dx} > 0$.

Proposition 5 shows that under the condition of $h > \frac{1}{2}rx(2a-2c-rx)$, when consumer returns rise, the retailer should increase the retail price and decrease order quantity. However, under the condition of $\frac{1}{4}rx(a-c+rx) < h < \frac{1}{2}rx(2a-2c-rx)$, the retailer should reduce the retail price and increase the order quantity to cope with the increase in consumer returns.

Furthermore, the degree of the retail price and order quantity being affected by the consumer return rate depends on the service cost.

Proposition 6 $\frac{d\lambda^*_{VI}}{dx} > \frac{d\lambda^*_{MS}}{dx} > 0$, $\frac{d\Pi^{VI}_{SC}}{dx} < \frac{d\Pi^{MS}_{SC}}{dx} < 0$ and $\frac{d\Pi^{MS}_{M}}{dx} < \frac{d\Pi^{MS}_{R}}{dx} < 0$.

From Proposition 6, we obtain that when consumer returns increase, the retailer should lower the service level. In addition, the optimal service level in the MS game is more largely affected by consumer returns than that in the VI game. We also conclude that the profit of the whole supply chain in the MS game is more largely affected by consumer return rate than that in the VI game. Furthermore, the retailer's profit is more largely affected by the consumer return rate than the manufacturer's profit in the MS game.

6 Conclusion

In this paper, we examine how to trade off the loss and profit brought by providing service in a single supply chain consisting of a manufacturer and a retailer under consumer returns. We obtain the optimal price, service level decisions and profits in the VI game and the MS game, respectively. Furthermore, through comparing the optimal profits with service provision with those of no service provision, we obtain the conditions where the retailer's service should be provided. We conclude that in the MS game the retailer should provide services. However, in the VI game, whether the service should be provided is restrained by the service cost. Finally, we derive that in the case of service provision, the profit of the supply chain in the MS game is more largely affected by consumer returns than that in the VI game.

In the future, we will consider the strategic consumer behavior in the model, and investigate how the presence of strategic consumer behavior impacts the retailer's or the manufacturer's decisions.

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顾客退货条件下的供应链定价和零售商服务水平决策

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摘要:为了研究顾客退货条件下的供应链最优价格和服务水平决策,构建了零售商提供服务下的顾客退货模型,分别在垂直集成博弈和制造商为斯坦伯格主导者博弈下得出了最优决策结果和最优利润. 通过与不提供服务情形下的最优利润进行对比,得出了零售商应该提供服务的边界条件. 结果表明:制造商为斯坦伯格主导者博弈下,提供服务的零售商和制造商比无服务提供的总是获得更高的利润;而垂直集成博弈下的供应链应该在某一特定条件下提供服务. 最后,通过数值举例,分析了提供服务的成本和退货概率的变化对最优决策的影响.

关键词:定价决策;服务水平;顾客退货;斯坦伯格博弈;垂直集成

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