ISSN: 2688-9323

Research on Supply Chain Pricing Decisions Considering Returns and Product Quality

Fengshan Si, Zhen Yu, Jing Wang

School of Management Science and Engineering, Anhui University of Finance and Economics, Bengbu 233030, China

Abstract

With the popularization of e-commerce, the return rate of online shopping platform is soaring. How to effectively deal with product return and control the return rate has become a pressing economic problem. This paper investigates the pricing strategy and product quality level decision through establishing a Stackelberg game model considering quality factor in a two-echelon supply chain composed of a manufacturer and an online retailer. We use backward induction to find the optimal equilibrium solution and conduct numerical simulation experiments to discuss the influence of relevant parameters on the optimal profit and quality level of the supply chain members. The findings suggest that improving product quality is beneficial to all stakeholders, especially the online retailer, moreover, high return rate hurts the payoffs of all supply chain members. When the return rate is low, customers become more sensitive to product quality, the profits of the manufacturer and the retailer increase significantly.

Keywords

Supply Chain Pricing; Consumer Return; Quality Level; Stackelberg Game.

1. Introduction

In recent years, with the rapid development of e-commerce, online shopping has become more widespread and popular. At the same time, the return rate of online products has increased dramatically, which makes it impossible to ignore the negative impact of consumers' frequent return in economic activities. Consumers can obtain product information from online virtual e-commerce platforms such as Jingdong, Tmall supermarket and so on, but they cannot touch the actual product directly, they can only estimate the quality and value of products through text, pictures, videos and partial buyer shows and make a decision whether to buy or not. The separation of consumer purchasing behavior and product experience leads to a certain perception difference between the version, material and color of the received products and consumers' expectations. The survey found that the return rate for the 2022 Singles' Day shopping festival reached 45 percent, about 5 percent higher than last year. Most consumers choose to return products because the quality is not up to their expectations. The higher the return rate is, the higher the corresponding inventory and retail expense will be. If retailers would like to control their profits, they must raise the sale price. However, for the same product, raising the price will further enhance the return rate, which makes the online retail market fall into a vicious circle, and enterprises have to consider the frequent return behavior of consumers and control the quality of products when carrying out production and sales activities.

2. Literature Review

This paper studies the impact of consumer return behavior on the profits of supply chain members and whether the manufacturer has the incentive to improve product quality to acquire higher economic benefits. The relevant literature covers two streams including consumer return and quality improvement. A considerable number of empirical studies introduce return factor into supply chain game model to examine the effect of consumer return behavior on firms' pricing and order quantity decisions. Chen et al.[1] study how competing retailers choose return policies and develop pricing strategies, and the results suggest that both high-quality and low-quality retailers should offer money-back guarantees. Li et al.[2] discuss the effect of full refund policy on manufacturer's and retailer's profits in direct or indirect channels. Khouja et al.[3] analyze the influence of the duration of return policies on retailers offering periodic returns. The aforementioned literature mainly focuses on the impact of return policy enforcement on the decision-making of supply chain members.

When it comes to the reasons for returns, everyone immediately supposes that the quality of products cannot meet the requirements of consumers. In the existing literature, the quality factor of products is also widely studied by scholars. Huang et al.[4] consider the bounded rationality of consumers and studied the optimal return competition strategy of retailers with different product quality and competing with each other. Pei[5] explores the relationship between product quality and return rate, constructs a dual channel supply chain model considering product quality level, and studied the pricing decisions of the manufacturer and the retailer under uniform pricing and autonomous pricing. Huang et al.[6] set the wholesale price and the retail price as exogenous variables, take product quality and service as decision variables, and formulate three different power structure supply chain models to research the influence of money back guarantee on product quality and service decisions. Wang and Dai[7] study the effects of return freight insurance on product price and quality under three different freight insurance strategies. The above literatures pay more attention to the selection of return policies and analyze the relationship between product quality factors and return rate. Based on the preceding discussion, this study takes the quality level as an endogenous variable and explores the pricing strategy and product quality decision by building a Stackelberg game model in a two-echelon supply chain.

3. Problem Description and Model Formulation

Table 1. Model notations and explanations

Notations	Explanations
w_i	Wholesale price per unit of product, decision variable, $i=1,2$
p_i	Retail price per unit of product, decision variable, $i=1,2$
D_i	The market demand of the online retailer, $i=1,2$
s	Salvage value of returned product per unit
k	Product return rate
b	The perceived sensitivity coefficient of quality, $b \in (0,1)$
m	The cost coefficient of improving product quality
λ	The effort level of improving product quality, decision variable
π_{mi}	The total profit of the manufacturer, $i=1,2$
π_{ri}	The total profit of the online retailer, $i=1,2$

Considering consumers' uncertain return behaviors, we investigate the pricing strategy and product quality level decision by building a Stackelberg leader-follower game model in a two-echelon supply chain consisting of a manufacturer and an online retailer. The manufacturer wholesales to the online retailer (the retailer for short) at the price of w, and then the retailer sells to the online shopping users at the price of p ($p > w$) through the online shopping platform. Online shoppers choose their favorite products according to their preferences and generate orders, they also can return the products they don't like to the original retailer and enjoy full refund service after the retailer receives the returned goods. Without loss of generality, we assume that both the manufacturer's marginal production cost and the retailer's marginal retailing cost are zero as most scholars have done before, each customer is limited to purchase no more than one unit of demand, and the market size is normalized to 1 to simplify the model and facilitate calculation. In addition, we also believe that unit returned good has a salvage value s, which is given exogenously and satisfies $s < w$. Two different cases are discussed and analyzed: baseline model without considering quality level, comparison model with considering quality level, the relevant parameters and variables are listed in Table 1.

3.1. Without Considering Quality Level

This paper considers a two-level supply chain composed of a manufacturer and an online retailer, where the manufacturer is the leader and the retailer is the follower. The manufacturer first decides the wholesale price, and then the retailer determines the sale price. The market demand is affected by the price and quality of the product, the higher the price, the less the demand, in contrast, the better the quality, the higher the demand. We also assume that the price sensitivity factor affecting the demand is 1, which is a very common practice, therefore, the demand function is defined as $D_i = 1 - p_i + b\lambda$. In the base model, the quality level λ is zero, the demand functions of the two cases are $D_1 = 1 - p_1$ and $D_2 = 1 - p_2 + b\lambda$, respectively. The profit functions of the manufacturer and the retailer are given as follows.

The profit function of the manufacturer is:

$$\pi_{m1}(w_1) = w_1(1 - p_1) \tag{1}$$

The profit function of the retailer is:

$$\pi_{r1}(p_1) = (p_1 - w_1)(1 - p_1) - (p_1 - s)k(1 - p_1) \tag{2}$$

We use backward induction to obtain the optimal pricing decisions and profits of the members. Firstly, starting from the retailer's profit function, we can obtain the reaction function $p_1(w) = \dfrac{1 - k + w - ks}{2(1-k)}$ by taking derivative, substitute $p_1(w)$ into the profit function of the manufacturer, at this time, the profit function contains only one variable, wholesale price, take derivative again to find the optimal wholesale price, and substitute the optimal result into the response function, demand function and two profit functions to get the optimal solution.

Proposition 1. When quality improvement measures are not implemented, the optimal consumer demand is $D_1^* = \dfrac{1 - k + ks}{4(1-k)}$, the optimal wholesale price of the manufacturer is $w_1^* = \dfrac{1 - k + ks}{2}$, the optimal retail price of the retailer is $p_1^* = \dfrac{3(1-k) - ks}{4(1-k)}$, and their optimal profits are $\pi_{m1}^* = \dfrac{(1 - k + ks)^2}{8(1-k)}$ and $\pi_{r1}^* = \dfrac{(1 - k + ks)^2}{16(1-k)}$, respectively.

Proposition 1 shows that the wholesale price of the manufacturer and the retail price of the retailer are merely related to the return rate and salvage value without considering the quality factor. The demand increases as the salvage value increases, and likewise as the return rate increases. Intriguingly, at this point, the profit of this manufacturer is twice that of this retailer.

3.2. With Considering Quality Level

In this section, apart from the wholesale price, the manufacturer also need to decide whether to increase investment or introduce advanced production technology for product quality improvement, and if so, how much to increase, so that the manufacturer can maximize the profit. In this case, the demand function is $D_2 = 1 - p_2 + b\lambda$, b refers to demand sensitivity with regard to quality level and λ denotes the effort level of the manufacturer to boost the product quality. Furthermore, referring to preceding research, we set the cost function to the form of quadratic function which has been widely used in the article, by doing so, the profit functions of the channel members are expressed as follows:

The profit function of the manufacturer is:

$$\pi_{m2}(w_2, \lambda) = w_2(1 - p_2 + b\lambda) - \frac{1}{2}m\lambda^2 \tag{3}$$

The profit function of the retailer is:

$$\pi_{r2}(p_2) = (p_2 - w_2)(1 - p_2 + b\lambda) - (p_2 - s)k(1 - p_2 + b\lambda) \tag{4}$$

In a similar manner, we derive the equilibrium decisions by backward induction. Similarly, we gain the reaction function $p_2(w) = \dfrac{(1-k)(1+b\lambda) + w - ks}{2(1-k)}$ as well, different from the previous model, the manufacturer has two decision variables, we work out the Hessian matrix $\mathrm{H} = \begin{bmatrix} \dfrac{1}{k-1} & \dfrac{b}{2} \\ \dfrac{b}{2} & -m \end{bmatrix}$ about w_2 and λ through taking partial derivatives. When the inequality $4m > b^2(1-k)$ is established, the profit function of the manufacturer is a convex function with a unique maximum value, the optimal solution can be found by letting the first partial derivatives to 0 respectively and solving linear equations.

Proposition 2. When actions are taken to improve product quality, the optimal consumer demand is $D_2^* = \dfrac{m(1-k+ks)}{(1-k)(4m+(k-1)b^2)}$, the optimal wholesale price and quality level of the manufacturer are $w_2^* = \dfrac{2m(1-k+ks)}{4m+(k-1)b^2}$ and $\lambda^* = \dfrac{b(1-k+ks)}{4m+(k-1)b^2}$, the optimal retail price of the retailer is $p_2^* = \dfrac{b^2(k-1)ks + m(3k-3+ks)}{(k-1)(4m+(k-1)b^2)}$. Likewise, their optimal profits are respectively $\pi_{m2}^* = \dfrac{m(1-k+ks)^2}{2(1-k)(4m+(k-1)b^2)}$ and $\pi_{r2}^* = \dfrac{m^2(1-k+ks)^2}{(1-k)(4m+(k-1)b^2)^2}$.

Proposition 2 notes that when the quality level of products produced by the manufacturer advances, the wholesale price of the manufacturer and the retail price of the retailer are not only affected by the return rate and salvage value, but also associated with the response degree of demand to product quality and the cost coefficient of quality level, so is the quality decision of the manufacturer. Furthermore, the optimal profit relationship between the two firms is no longer a simple twofold relationship, the optimal profit of the manufacturer is less than twice that of the retailer, and even less than the total profit of the retailer.

In order to identify whether the manufacturer is willing to upgrade the product quality, we make a comparison with the optimal profit results mentioned above and obtain proposition 3.

Proposition 3. Improving product quality is conducive to both the manufacturer and the online retailer, especially the online retailer.

Proof . When quality improvement measures are taken or production activities are carried out according to the original plan, the profit difference between the manufacturer and the retailer is shown in equation (5) and equation (6) respectively. Owing to $4m > b^2(1-k)$, $0 < \mathrm{b} < 1$, $0 < k < 1$, $m > 0$, $s > 0$, it can be inferred that both $\Delta\pi_m$ and $\Delta\pi_r$ are positive. Similarly, by observing formula (7), we can see that the ratio of $\Delta\pi_m$ to $\Delta\pi_r$ is less than one, that is, $\Delta\pi_m < \Delta\pi_r$.

$$\Delta\pi_m = \pi_{\mathrm{m}2} - \pi_{m1} = \frac{b^2(1-k+ks)^2}{8(4m+(k-1)b^2)} \tag{5}$$

$$\Delta\pi_r = \pi_{r2} - \pi_{r1} = \frac{b^2(8m+(k-1)b^2)(1-k+ks)^2}{16(4m+(k-1)b^2)^2} \tag{6}$$

$$\frac{\Delta\pi_m}{\Delta\pi_r} = \frac{8m+2(k-1)b^2}{8m+(k-1)b^2} \tag{7}$$

As stated in proposition 3, improving product quality can raise the overall profit of the supply chain. Any increase in production costs of the manufacturer inevitably leads to a corresponding hike in both the wholesale and retail prices. Although quality improvements may spur an increase in demand, this cannot fully offset the decrease in demand resulting from the higher retail price, causing an overall decline in total market demand. In the case of the constant return rate, the increase in income resulting from the higher price exceeds the loss of income resulting from decreased demand. Furthermore, it is worth noting that as product quality enhances, the product return rate tends to drop off and the demand is growing gradually over time, because consumers are more likely to actively share and recommend the product to their friends and families after having a well-pleasing shopping experience. As a result, consumers are willing to buy high-quality products at higher prices and the number of returned goods will decrease, so the manufacturer and the retailer can obtain higher profits and better brand reputation. In this way, the manufacturer is more motivated to produce more high-quality products and the retailer has more motivation to sell more goods, which is helpful to the sustainable development of social economy.

4. Numerical Simulation

In order to verify the validity and accuracy of the above theoretical model and explore more interesting phenomena, MATLAB mathematical software is utilized to carry out numerical analysis by materializing the parameters and visualizing the results. Based on the quality model considering returns, we discuss the effects of the return rate, the cost coefficient and the sensitivity coefficient on the profits of the manufacturer and the online retailer in different

ISSN: 2688-9323

situations and compare their profits with those without considering quality factor. In addition, we also analyze the correlation between the quality level and the return rate, the cost coefficient, the sensitivity coefficient and the salvage value.

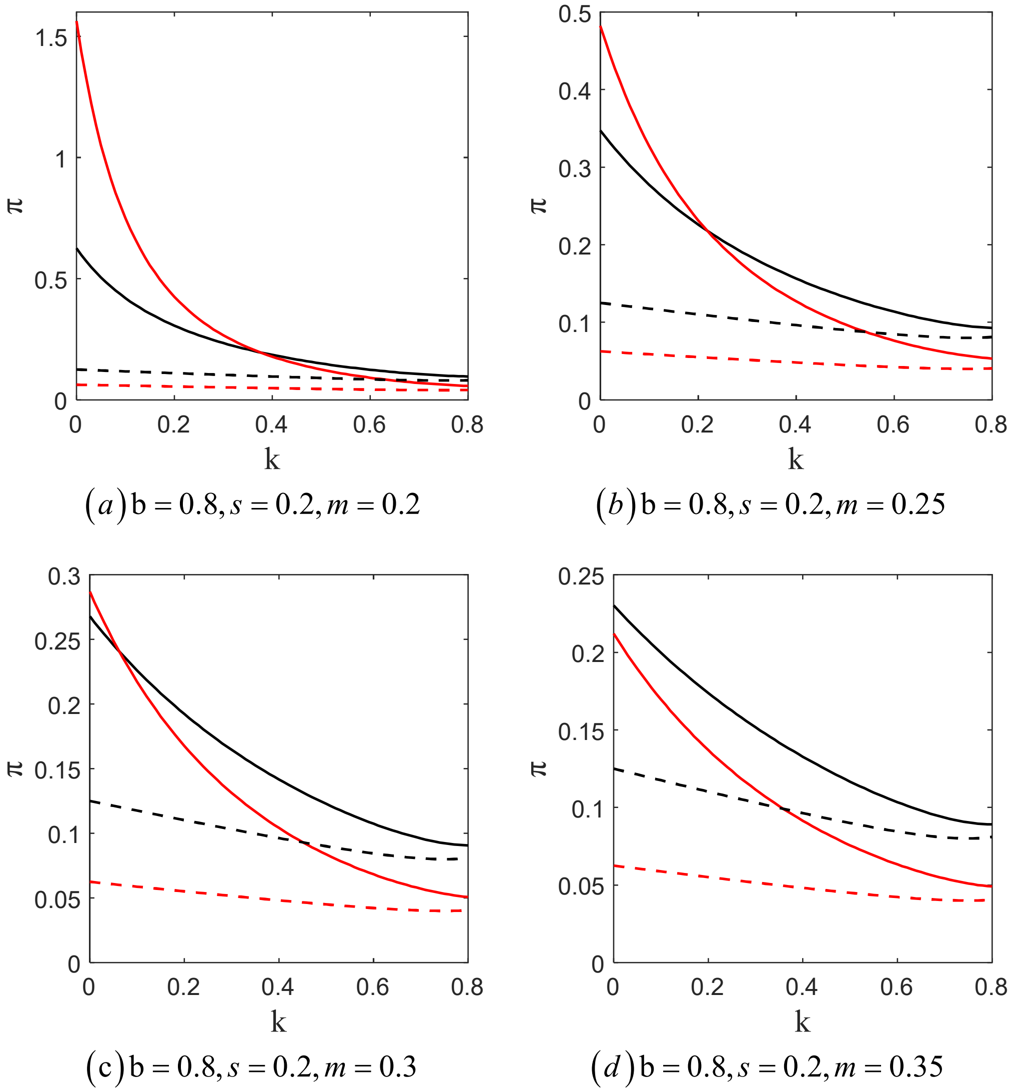
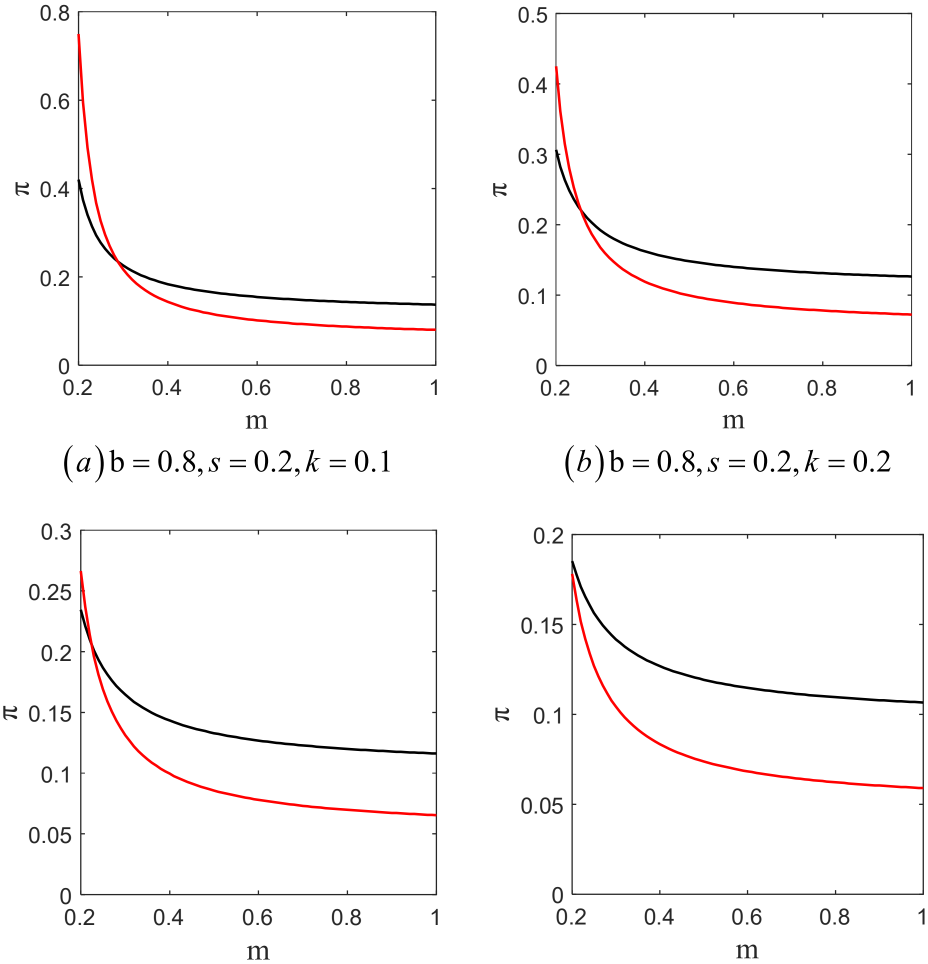


Figure 1. The effect of return rate on the payoffs under different cost coefficients

As shown in Figure 1, the black line represents the manufacturer's profit, and the red line represents the retailer's profit, figure 2 and figure 3 are the same. For both the manufacturer and the retailer, the profit from quality improvement is consistently higher than without quality improvement. While improving quality, with the increase of the return rate, the payoffs of both the manufacturers and the retailer will decline rapidly. When the return rate is low, retailers will take the main profit of the market, in contrast, the manufacturer gains the main market profit when the return rate is high. The focus in the figure indicates that the profit of the manufacturer is equal to that of the retailer, and the value of m changes the position of the focus and the profit range dramatically.

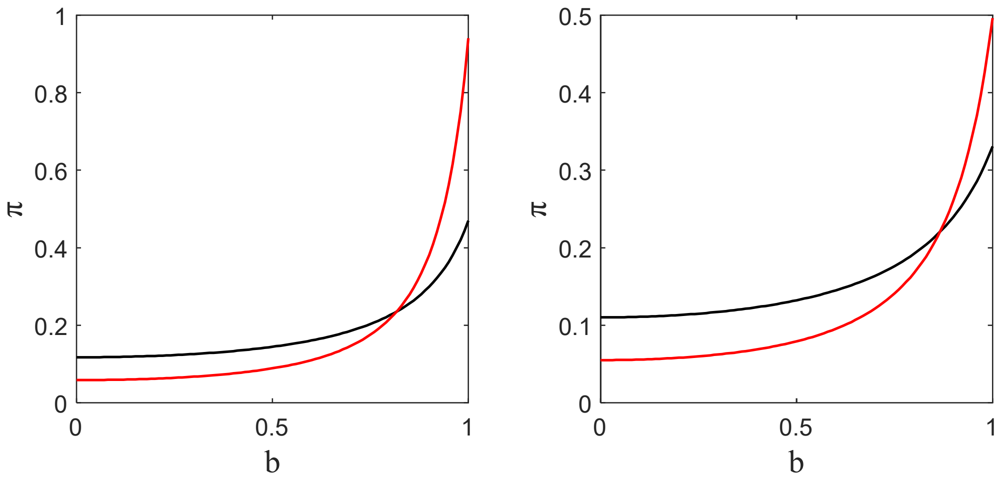
Figure 2 illustrates that the increase in the cost coefficient has led to a sharp drop in overall supply chain payoffs, which implies that if the cost of improving quality is too high, the manufacturer is reluctant to implement quality improvement measures. Because it is not economic to spend a large amount of effort, time and money to enhance product quality, but the profit is only a little bit more than before. Comparing the four graphs in Figure 2, it can be seen that the increase in the return rate has reduced the overall profit of the supply chain.



(a) b $= 0.8, s = 0.2, k = 0.1$ (b) b $= 0.8, s = 0.2, k = 0.2$

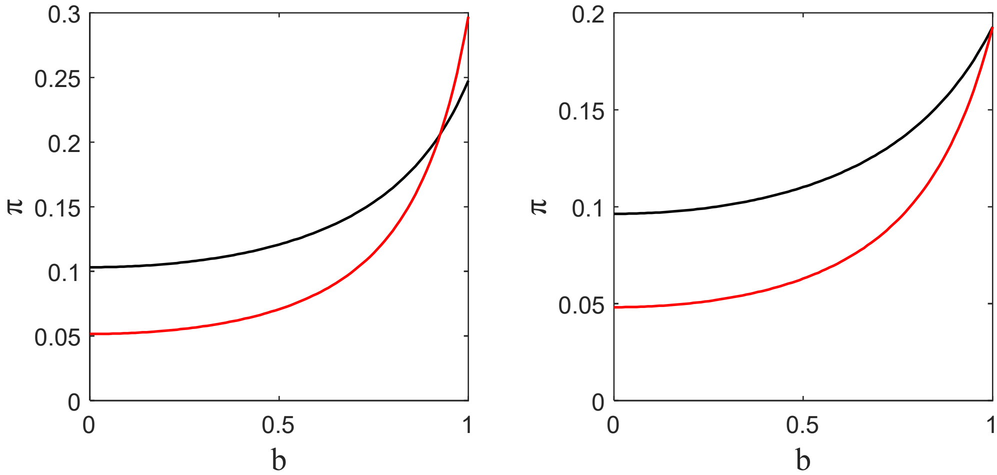
(c) b $= 0.8, s = 0.2, k = 0.3$ (d) b $= 0.8, s = 0.2, k = 0.4$

Figure 2. The effect of cost coefficient m on the profits under different return rates



$(a)\, m = 0.3, s = 0.2, k = 0.1$ $(b)\, m = 0.3, s = 0.2, k = 0.2$

ISSN: 2688-9323

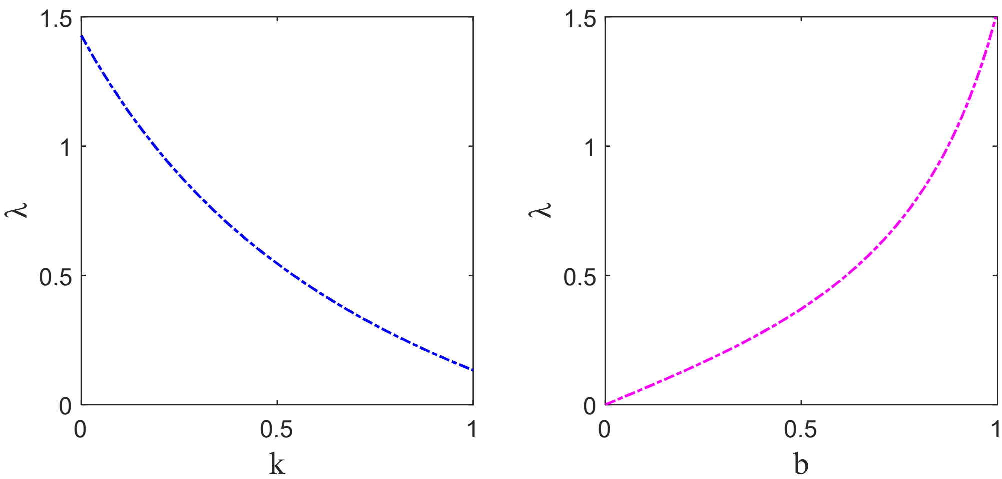


(c) $m = 0.3, s = 0.2, k = 0.3$ (d) $m = 0.3, s = 0.2, k = 0.4$

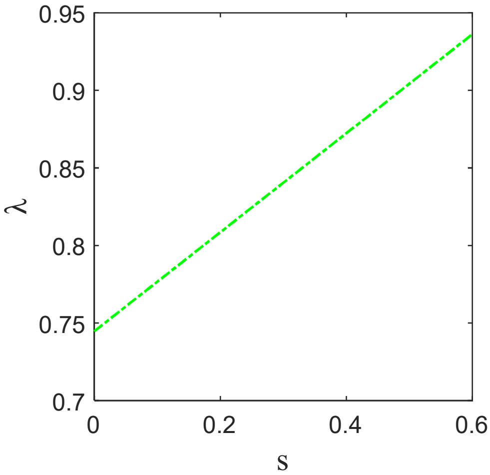
Figure 3. The effect of sensitivity coefficient on the profits under different return rates

As depicted in figure 3, the profits of the manufacturer and the retailer increase with the customer's perceived sensitivity to quality, this reveals that if customers are more sensitive to product quality, the manufacturer had better carry out quality reform. The reason is that when consumers are extremely sensitive to product quality, enhancing product quality leads to a rapid increase in the overall payoffs of the supply chain.

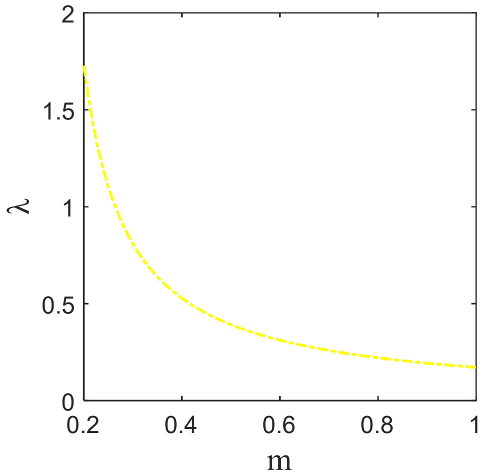
By observing the expression of quality decision equilibrium, we notice that the product quality is affected by the return rate, salvage value, quality sensitivity coefficient and cost coefficient. Figure 4 indicates that the return rate and cost coefficient inhibit quality enhancement, whereas the quality sensitivity and salvage value stimulate the promotion of product quality. Only the salvage value has a linear impact on the optimal quality level, while the effect of the other three parameters is nonlinear, among them, the most influential factor is the cost coefficient, which is also in line with the practical situation.



(a) $b = 0.8, m = 0.3, s = 0.2$ (b) $k = 0.3, m = 0.3, s = 0.2$



(c) b = 0.8, $k = 0.3, m = 0.3$



(d) b = 0.8, $k = 0.3, s = 0.2$

Figure 4. Influence analysis of the optimal quality level

5. Conclusion

This paper constructs a Stackelberg game model to investigate the pricing strategy and product quality level decision in a two-echelon supply chain including a manufacturer and a retailer, in which the manufacturer takes a dominate position. Through backward induction, we can derive the optimal pricing decisions and equilibrium payoffs of firms and draw several conclusions. Raising the level of product quality is good for both the manufacturer and the online retailer, especially the online retailer. While improving quality, the payoffs of both the manufacturer and the retailer will decline rapidly with the increase of the return rate. Similarly, the increase in the cost coefficient will lead to a sharp drop in overall supply chain payoffs. On the contrary, the profits of the manufacturer and the retailer increase as customers become more sensitive to product quality. As for the quality level, the return rate and cost coefficient restrain quality enhancement, whereas the quality sensitivity and salvage value promote the improvement of product quality.

According to our research, the following suggestions are put forward. The manufacturer should conduct quality control and strengthen production technology innovation consciously and positively. In the era of rapid development of information and science and technology, only through improving the quality of products and satisfying the service experience of consumers, can enterprises be competitive in the highly competitive market. The retailer should emphasize the quality advantages of their products and provide complete pre-sales consultation and after-sales service.

There are still some limitations in this study. First of all, this paper assumes that the return rate of the product is exogenous and constant. In practice, improving product quality level will relatively reduce the return rate of merchandise sales. Second, this paper does not consider the product price competition and quality competition. Future studies can consider competitive market environment or define the product return rate as an endogenous variable.

Acknowledgments

The authors thank the reviewers for their careful reading and pertinent suggestions. This work was supported by the Natural Science Research Project of Education Department in Anhui Province (2022AH050589); the School-level Science Research Project of Anhui University of Finance and Economics (ACKYB22015); the Graduate Research Innovation Fund Project of Anhui University of Finance and Economics (ACYC2022059).

ISSN: 2688-9323

Conflicts of Interest

The authors declare no conflict of interest.

References

[1] J. Chen, B.T. Chen and W. Li: Who should be pricing leader in the presence of customer returns, European Journal of Operational Research, Vol. 265 (2018) No.2, p.735-747.

[2] G. Li, L. Li, S.P. Sethi, et al. Return strategy and pricing in a dual-channel supply chain, International Journal of Production Economics, Vol. 215 (2019) p.153-164.

[3] M. Khouja, H. Ajjan and X. Liu: The effect of return and price adjustment policies on a retailer's performance, European Journal of Operational Research, Vol. 276 (2019) No.2, p.466-482.

[4] Z.S. Huang, J.J. Nie and Y.X. Zhao: Money-back guarantees in the presence of bounded rational consumers, Chinese Journal of Management Science, Vol. 24 (2016) No.1, p.116-123.

[5] J.X. Pei: Decision analysis of dual-channel supply chain with quality and customer returns, Logistics Sci-Tech, Vol. 42 (2019) No.6, p.157-161.

[6] F. Huang, H.M. Song, H. Yang, et al. The impact of money back guarantees on quality and service of supply chain products, Industrial Engineering and Management, Vol. 24 (2019) No.3, p.35-42.

[7] J.H. Wang, Q. W. Dai: Research on product price and quality decision based on return insurance, Logistics Sci-Tech, Vol. 45 (2022) No.5, p.1-6.