The suppliers' strategy choices in retailer-dominated supply chain

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Abstract: This paper analyzes how the suppliers should do to make the right strategic choices; their profits can be improved through cooperation and jointly pricing, while suppliers can also take certain measures to adjust its product performance thereby adjusting demand-price elasticity to get more profits. The results show that based on the cooperation mechanism of joint pricing, suppliers can adjust the demand-price elasticity to compensate for their disadvantage.

Keywords: retailer-dominated; strategic choices; demand-price elasticity

INTRODUCTION

Over the past few decades, we have witnessed more and more retailers. Along with the international retail giants Carrefour, WAL-MART and other chain groups swarming into China, Chinese local household appliance retail giants Suning and Gome are also in rapid development.. In this kind of supply chains, the contradiction between the suppliers and the retailers are soaring.

This paper tends to study the coordination of suppliers and performance of supply chain in the market led by retailers. Chen et al. (2009) analyzed the collaborative problems of retailers' demand disruptions and the supply chain coordination. Chiu et al. (2015) considered the coordination challenge with a risk-neutral manufacturer which suppliers to multiple heterogeneous retailers. Wang et al. (2007) explained how to achieve synergy in the retailer leading supply chain with the optional contract. Raju et al. (2005) analyzed the optimal strategy and supply chain collaborative supply chain model based on the analysis of the retailer dominant to the suppliers.

The literature mentioned above mainly analyzed the impact of supply chain revenue in retailer-dominated supply chain, but the retailers truly achieving the dominant position is mainly presented in their owning more choice of strategies. At present, many researchers are studying retailers providing contract price strategy to different suppliers, including percentage price strategy (such as setting 120% of supplier's wholesale price as final retail price) and fixed price strategy (such as setting 20 Yuan plus supplier's wholesale price as final retail price). Many scholars have compared these two different strategies. Using Stackelberg model, Tyagi et al. (2005) showed that the dominant retail business will be more inclined to the percentage price strategy facing multiple suppliers. Wang et al. (2013) compared two kinds of price strategies, and showed that price strategies and the percentage of retailers in the supply chain revenue will increase compared with the fixed price strategy, while supply revenue will decrease.

As the dominant retailer is strong, some scholars also gives the corresponding strategies on how to ensure the profit of suppliers. Geylani et al.(2004) proposes that in the face of a monopoly retailer and a relatively weak retailer, through joint promotions and advertising, manufacturers will transfer demand to relatively weak retailers so as to ensure their profits; Li et al.(2008) stated that through sharing information, all parties involved in the centralized decision-making to obtained Lower equilibrium price and higher earnings.

Through the comparison of profit of retailer, suppliers, and whole supply chain in different cases, we find that the profit of suppliers in cooperation case is more than that in competition case, so suppliers tend to cooperate with each other; they can also adjust the price elasticity of demand to obtain greater benefits in cooperation case. Finally, numerical experiments are carried out to illustrate the theoretical result, and further illustrations for our results are given.

BASIC MODEL

Our paper considers a retailer-dominated supply chain including two suppliers ($S_i, i=1,2$), and one retailer (R) who has larger power than that of former. Both two suppliers provide substitute products to retailer. Let the unit cost of each product provided be c, ignoring costs resulted from dominated retailer.

Competition of substitute products is considered in our paper. According to previous studies, we assume that market demands of products are mainly affected by not only own wholesale price but the rival's price. Therefore, the demand function follows the exponential form expressed as equation (1).

$$D_i = \lambda p_i^{-\alpha} p_j^{\beta}, i=1,2, j=3-i \qquad (1)$$

Where p_i represents the wholesale price set by supplier S_i, p_j refers to another supplier's price. Obviously, the demand of products provided by supplier S_i is a decreasing function of its own price，but will increase with the rival's wholesale price. The demand function can also be rewritten into the form $D_i = \lambda p_i^{-(\alpha-\beta)}(p_j / p_i)^{\beta}$， $\lambda p_i^{-(\alpha-\beta)}$ reflects the degree of competition from the wholesale price of the substitute products，$(p_j / p_i)^{\beta}$ reflects the degree of competition in two kinds of product price. α， β are the price elasticity parameters related to the performance of products. We assume that $\alpha - \beta > 1$ which ensures demand does not increase with the increase of price and $\beta > 0$ which represents the substitutability of the products provided by different suppliers.

Our paper assumes that the supplier and the retailer are risk neutral. A Stackelberg game between the dominated retailer and the suppliers is considered. As Stackelberg leader, retailer first sets his price percentage η , then the two suppliers to determine their wholesale price w_i , so retailer pricing of products can be given by $p_i = (1+\eta)w_i$. Based on the decisions of retailer and suppliers, market demand realizes. Furthermore, we will discuss different relationship of the two suppliers: competition case and corporation case. The timeline of all events in the model can be showed in Figure 1.

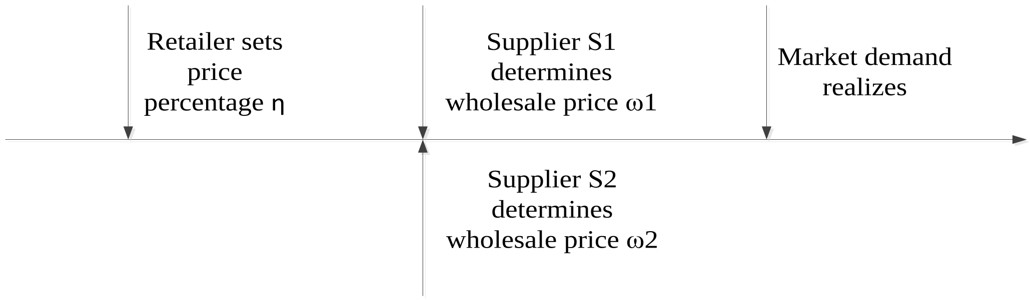

Fig.1 Timeline of the events in the model

EQUILIBRIUM SOLUTION OF STACKELBERG MODEL

Suppliers' competition case

As the Stackelberg leader, retailer takes into account the profit-maximizing actions of the suppliers and simultaneously sets price percentage η . After the suppliers S_i know the price percentage η , they will choose wholesale price w_i to maximize their own profits.

According to the rules of the game we use backward induction method to find equilibrium solutions to the model. First, we solve the suppliers' expected profit function based on the given price percentage. The profits of suppliers who compete with each other are as follows:

$$\max_{w_i} \ \pi_S^i = \lambda(1+\eta)^{-(\alpha-\beta)} w_i^{-\alpha} w_j^{\beta} (w_i - c), i = 1, 2, j = 3-i \quad (2)$$

It is easy to find that the profit function is a concave function of wholesale price. Then, we calculate the Nash equilibrium solution according to the first-order condition,

$$\frac{\partial \pi_S^1}{\partial w_1} = \lambda(1+\eta)^{-(\alpha-\beta)} w_2^{\beta} [-\alpha w_1^{-(\alpha+1)} (w_1 - c) + w_1^{-\alpha}] = 0 \quad (3)$$

$$\frac{\partial \pi_S^2}{\partial w_2} = \lambda(1+\eta)^{-(\alpha-\beta)} w_1^{\beta} [-\alpha w_2^{-(\alpha+1)} (w_2 - c) + w_2^{-\alpha}] = 0 \quad (4)$$

From equations (3) and (4), it is not difficult to get the optimal wholesale prices:

$$w_i^* = w_i(\eta) = \frac{\alpha c}{\alpha - 1}, i = 1, 2 \quad (5)$$

Second, we maximize the profit function to obtain the optimal price percentage after the optimal action of manufacturer is derived. The profit of retailer is given by:

$$\max_{\eta} \ \pi_R = \sum_{i=1}^{2} \lambda (1+\eta)^{-(\alpha-\beta)} w_i^{*-\alpha} w_i^{*\beta} \eta w_i^*, i = 1,2 \tag{6}$$

Therefore, the optimal price percentage for retailer can be expressed by $\eta^* = \dfrac{1}{\alpha-\beta-1}$ (7)

So we can get the optimal profits of the supplier, retailer and the whole supply chain

$$\pi_S^{i*} = \frac{\lambda c}{\alpha-1} [\frac{(\alpha-1)(\alpha-\beta-1)}{(\alpha-\beta)\alpha c}]^{\alpha-\beta}, i = 1,2 \tag{8}$$

$$\pi_R^* = \frac{2\lambda}{\alpha-\beta} [\frac{(\alpha-1)(\alpha-\beta-1)}{(\alpha-\beta)\alpha c}]^{\alpha-\beta-1} \tag{9}$$

$$\pi_T^* = \sum_{i=1}^{2} \pi_S^i + \pi_R^* = \frac{2\lambda(2\alpha-\beta-1)}{(\alpha-\beta)\alpha} [\frac{(\alpha-1)(\alpha-\beta-1)}{(\alpha-\beta)\alpha c}]^{\alpha-\beta-1} \tag{10}$$

Suppliers' cooperation case

If the suppliers choose to cooperate with each other, they will choose the same wholesale price w_{iT} to maximize their profits. We also adopt backward induction to derive the optimal decisions for retailer and suppliers.

$$\max_{w_{iT}} \pi_{ST} = \sum_{i=1}^{2} \lambda (1+\eta_T)^{-(\alpha-\beta)} w_{iT}^{-(\alpha-\beta)} (w_{iT} - c \quad i =) , \tag{11}$$

As one can easily confirm, the profit function is a concave function of wholesale price. Through the first-order condition, we obtain the optimal wholesale price for the two corporate suppliers which can be given by:

$$w_{iT}^* = w_{iT}(\eta_T) = \frac{(\alpha-\beta)c}{\alpha-\beta-1}, i = 1,2 \tag{12}$$

Similarly, the retailer takes action which is the most beneficial to his profit,

$$\eta_T^* \in \arg\max_{\eta_T} \ \pi_{RT} = \sum_{i=1}^{2} \lambda (1+\eta_T)^{-(\alpha-\beta)} w_{iT}^{*\,-(\alpha-\beta)} \eta_T w_{iT}^*, i = 1,2 \tag{13}$$

It is easy to get the optimal price percentage for retailer which can be expressed by

$$\eta_T^* = \eta^* = \frac{1}{\alpha-\beta-1} \tag{14}$$

Compared with the optimal price percentage set by the suppliers who compete with each other, we can find that the retailer will determine the same price percentage η^* under competition case and cooperation case of suppliers. Similarly, the profits of suppliers, retailer and the whole supply chain are: $$\pi_{ST}^* = \frac{2\lambda c}{\alpha-\beta-1}\left[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}\right]^{\alpha-\beta} \quad (15)$$

$$\pi_{RT}^* = \frac{2\lambda}{\alpha-\beta}\left[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}\right]^{\alpha-\beta-1} \quad (16)$$

$$\pi_{TT}^* = \pi_{ST}^* + \pi_{RT}^* = \frac{2\lambda(2\alpha-2\beta-1)}{(\alpha-\beta)^2}\left[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}\right]^{\alpha-\beta-} \quad (17)$$

RESULT ANALYSES

Profits analysis

We have obtained the optimal profits of retailer, suppliers and the whole supply chain; the results below are derived by comparing the optimal profits in different cases.

Proposition 1

(i) Sum of the suppliers' profits is larger in cooperation case than that in competition case;

(ii) Profit of retailer in cooperation case is less than that in competition case.

Proof: According to equations（8）and（15）, in order to prove that sum of the suppliers' profits is larger in cooperation case than that in competition case, that is $\pi_{ST}^* > \sum_{i=1}^{2}\pi_S^{i*}$, we need to prove the following inequality:

$$\frac{2\lambda c}{\alpha-\beta-1}\left[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}\right]^{\alpha-\beta} > \frac{2\lambda c}{\alpha-1}\left[\frac{(\alpha-1)(\alpha-\beta-1)}{\alpha(\alpha-\beta)c}\right]^{\alpha-\beta-1} \quad (18)$$

Simplifying inequality (18) we can get:

$$\frac{\alpha-1}{\alpha-\beta-1} > \left[\frac{(\alpha-\beta)(\alpha-1)}{\alpha(\alpha-\beta-1)}\right]^{\alpha-\beta}, \quad \alpha-\beta-1>\beta>0 \quad (19)$$

Sorting inequality (19) we obtain:

$$(\alpha-\beta)[\ln\alpha-\ln(\alpha-\beta)] > (\alpha-\beta-1)[\ln(\alpha-1)-\ln(\alpha-\beta-1)] \quad (20)$$

We should prove inequality（20）$H(t) = (t-\beta)[\ln t - \ln(t-\beta)](t>\beta>0)$ to be an increasing function. Take the derivative of $H(t)$, we can get the conclusion that $H'(t) = \ln\frac{1}{1-\beta/t} - \frac{\beta}{t}$ is always positive when $t>\beta>0$, so $H(\alpha) > H(\alpha-1)$. This means that the profits' sum of suppliers in cooperation case is bigger than that in competition case.

On the other hand, because equilibrium wholesale price in cooperation case is greater than that in competition case（$w_{iT}^* > w_i^*$）, it is not difficult to see $\pi_{RT}^* < \pi_R^*$.

According to proposition 1, although the bigger wholesale price in cooperation case results in the less market demand and the less supply of products, it brings in more revenue to the suppliers. Therefore, the positive effect on profits of suppliers from the increasing price is larger than the negative effect from the decreasing demand. However, the increase of wholesale price will lead directly to the decrease of retailer's profit.

Proposition 2 Increment of suppliers' profits in cooperation case is less than the decrement of retailer's profit. That is to say, the benefit of the whole supply chain will be reduced.

Proof: According to equations (10) and (17), in order to prove that the whole supply chain decrease when suppliers choose to cooperate, it needs to prove the following inequality to be set up.

$$\frac{2\lambda(2\alpha-2\beta-1)}{(\alpha-\beta)^2}\left[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}\right]^{\alpha-\beta-1} < \frac{2\lambda(2\alpha-\beta-1)}{(\alpha-\beta)\alpha}\left[\frac{(\alpha-1)(\alpha-\beta-1)}{(\alpha-\beta)\alpha c}\right]^{\alpha-\beta-1} \qquad (21)$$

Simplifying inequality (21) we can get:

$$\begin{aligned}&\ln(2\alpha-\beta-1)-\ln(2\alpha-2\beta-1)\\ &>(\alpha-\beta)[\ln\alpha-\ln(\alpha-\beta)]+(\alpha-\beta-1)[\ln(\alpha-1)-\ln\alpha]\end{aligned} \qquad (22)$$

Sorting inequality (22), the inequality below is true,

$$\ln\frac{2\alpha-\beta-1}{\alpha(\alpha-\beta-1)} > (1-\frac{1}{\alpha-\beta})\ln\frac{2\alpha-\beta-1}{(\alpha-1)(\alpha-\beta)}+\frac{1}{\alpha-\beta}\ln\frac{2\alpha-2\beta-1}{(\alpha-\beta-1)(\alpha-\beta)} \qquad (23)$$

According to the relationship between α and β, it's easy to deduce following inequality hold:

$$\frac{2\alpha-\beta-1}{\alpha(\alpha-\beta-1)} > (1-\frac{1}{\alpha-\beta})\frac{2\alpha-\beta-1}{(\alpha-1)(\alpha-\beta)}+\frac{2\alpha-2\beta-1}{(\alpha-\beta-1)(\alpha-\beta)^2} \qquad (24)$$

From concavity of logarithmic function, it can be deduced:

$$\begin{aligned}\ln\frac{2\alpha-\beta-1}{\alpha(\alpha-\beta-1)} &> \ln\left[(1-\frac{1}{\alpha-\beta})\frac{2\alpha-\beta-1}{(\alpha-1)(\alpha-\beta)}+\frac{1}{\alpha-\beta}\frac{2\alpha-2\beta-1}{(\alpha-\beta-1)(\alpha-\beta)}\right]\\ &> (1-\frac{1}{\alpha-\beta})\ln\frac{2\alpha-\beta-1}{(\alpha-1)(\alpha-\beta)}+\frac{1}{\alpha-\beta}\ln\frac{2\alpha-2\beta-1}{(\alpha-\beta-1)(\alpha-\beta)}\end{aligned}$$

Therefore, inequality (23) holds.

Proposition 2 shows that when the suppliers select to cooperate with each other, although the total revenue for suppliers increases, the retailer's profit will be greatly reduced, which can result in the decrease in profit of the whole supply chain, therefore, the effect of cooperation on retailer is much more than that on suppliers. Counter-intuitively, the competition among suppliers sometimes can bring in the increment of the whole supply chain's profit. So, for the entire market, as more competitive companies are involved, the efficiency of the whole supply chain will be promoted greater, which is more conducive to the operation of the market.

Proposition 3 In cooperation case, assuming that sharing proportion of supplier S_1 is θ, and that of supplier S_2 is $1-\theta$. Suppliers are willing to choose to cooperate with each other if $\theta\in[\underline{\theta},\overline{\theta}]$, where $\underline{\theta}=\frac{\alpha-\beta-1}{2(\alpha-1)}\left[\frac{(\alpha-\beta)(\alpha-1)}{\alpha(\alpha-\beta-1)}\right]^{\alpha-\beta}$, and $\overline{\theta}=1-\frac{\alpha-\beta-1}{2(\alpha-1)}\left[\frac{(\alpha-\beta)(\alpha-1)}{\alpha(\alpha-\beta-1)}\right]^{\alpha-\beta}$.

Although sum of suppliers' profits is larger in cooperation case than that in competition case, for each one it needs conditions to take part in cooperation. Proposition 3 provides the conditions that suppliers choose to cooperate, if sharing proportion of supplier S_1 satisfies $\theta\in[\underline{\theta},\overline{\theta}]$, their contract of association is valid.

Parameter analysis

The previous section has showed that it is even better when suppliers choose to cooperate, as well as the condition they choose to cooperate. This section will discuss the effect of price elasticity parameter α , β on profit of all participants in retailer-dominated supply chain in cooperation case. Aiming to illustrate how the suppliers should adjust product property to get more profits. From the above analysis and calculation, it is easy to get table 1（↓、→、↑ means decrease, invariant, increase）.

Tab.1 Equilibrium values of the variables change with α or β increasing

	Competition case	Relationship	Corporation case
w^*	$\frac{\alpha c}{\alpha-1}\begin{pmatrix}\alpha\downarrow\\ \beta\rightarrow\end{pmatrix}$	<	$\frac{(\alpha-\beta)c}{\alpha-\beta-1}\begin{pmatrix}\alpha\downarrow\\ \beta\uparrow\end{pmatrix}$
η^*	$\frac{1}{\alpha-\beta-1}\begin{pmatrix}\alpha\downarrow\\ \beta\uparrow\end{pmatrix}$	=	$\frac{1}{\alpha-\beta-1}\begin{pmatrix}\alpha\downarrow\\ \beta\uparrow\end{pmatrix}$
p^*	$\frac{(\alpha-\beta)\alpha c}{(\alpha-\beta-1)(\alpha-1)}\begin{pmatrix}\alpha\downarrow\\ \beta\uparrow\end{pmatrix}$	<	$\frac{(\alpha-\beta)^2 c}{(\alpha-\beta-1)^2}\begin{pmatrix}\alpha\downarrow\\ \beta\uparrow\end{pmatrix}$
D^*	$\lambda[\frac{(\alpha-\beta-1)(\alpha-1)}{(\alpha-\beta)\alpha c}]^{\alpha-\beta}\begin{pmatrix}\alpha\uparrow\\ \beta\downarrow\end{pmatrix}$	>	$\lambda[\frac{(\alpha-\beta-1)^2}{(\alpha-\beta)^2 c}]^{\alpha-\beta}\begin{pmatrix}\alpha\uparrow\\ \beta\downarrow\end{pmatrix}$

Table 1 illustrates that both α and β have an effect on wholesale price for supplier and price percentage for retailer, and it will further effects the profit of suppliers, retailer and the whole supply chain.

Proposition 4 Suppliers' profits in cooperation case π_{ST}^* satisfies：

（ i ） Given parameter β, unique $\alpha=\alpha^*\in(\beta+1,\beta+2)$ exists，which makes π_{ST}^* optimized.

（ ii ） Given parameter α, unique $\beta=\beta^*\in(\alpha-2,\alpha-1)$ exists，which makes π_{ST}^* optimized.

Proposition 4 indicates no matter for α or β, unique optimal value exists which makes π_{ST}^* optimal, and the optimal value can be predicted in a certain range. The profit of suppliers increases with the increase in α (β) for $\alpha<\alpha^*(\beta<\beta^*)$; the profit of suppliers decreases with the increase in α (β) for $\alpha>\alpha^*(\beta>\beta^*)$. Therefore, suppliers can get more profit through the adjustment of price elasticity with the methods of improving the product's property, increasing the propaganda dynamics and so on.

Similar to proposition 4, we can give the property of the benefit of retailer and supply chain.

Proposition 5 In cooperation case, the retailer's profit will decrease as α increases，and will increase as β increases.

Proposition 6 In cooperation case, the supply chain's profit will also decrease as α increases， and will increase as β increases.

Proof of Proposition 5 and proposition 6 are similar to proposition 4. Through the above three propositions, we can find some rules of profits of suppliers, retailer, and the whole supply chain in cooperation case. Furthermore, the effects of relative coefficient on the equilibrium solution are derived. In the face of supply chain led by retailer, through adjusting products' property and the price elasticity, suppliers can also maximize their own benefits, which can shake retailer' leading position in some extent.

NUMERICAL EXPERIMENT

In order to analyze the model and its related conclusion further and intuitively, the following text gives the specific example analysis .Firstly, we will analyze in the mechanisms of the cooperation and competition between the suppliers, and then we will analyze if the suppliers choose the mechanism which is good for them. The influence of price elasticity parameters on all returns and how the suppliers can adjust their product's price elastic to attain more benefits.

If we assume the value of the parameters in the modern are $\lambda = 100$, $c = 1$, because all parties' benefits in the supply chain are affected by two kinds of product price elastic coefficient, in order to analysis conveniently, fixed suppliers' S_2 product price elastic coefficient $\beta = 1$, discuss how the benefits of suppliers, retailer and the whole supply chain changed in response to the price elastic coefficient, showed as Fig.2-4

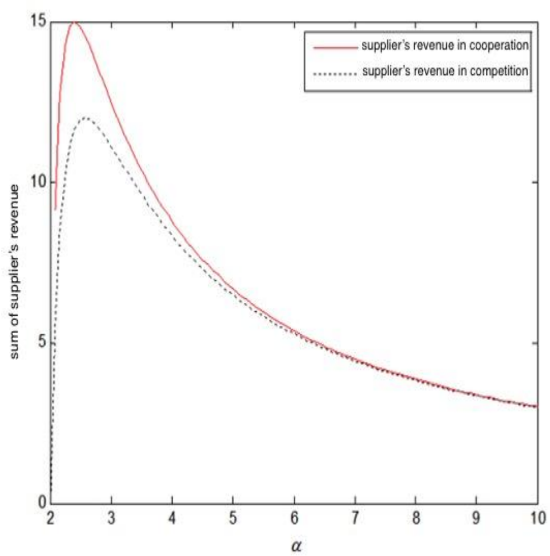

Fig.2 Suppliers' profits change with α

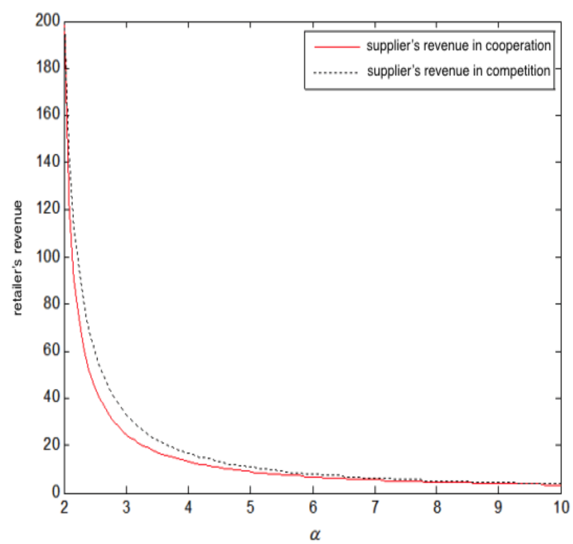

Fig.3 Retailer's profits change with α

It shows that the choice of suppliers' cooperation situation will get more profits compared with the competition, but at the same time, retailers and the benefits of the whole supply chain will decrease. Therefore, the cooperation mechanism protects the supply chain to a certain extent. Figure 5 illustrates the relationship between profit and price elasticity coefficient of different product s under the the mechanism of choosing more beneficial cooperations

As is described in proposition 4 and 5, while choose cooperation mechanism, suppliers must coordinate relations between the two kinds of product competition. There should be an optimum value for the difference between these two price elasticity indexes that maximize suppliers' revenue. Therefore, suppliers are always able to find the reasonable joint pricing mechanism as a optimal strategy choice. If given $\alpha = 0.25$, the parties in the supply chain benefits are shown in table 2.

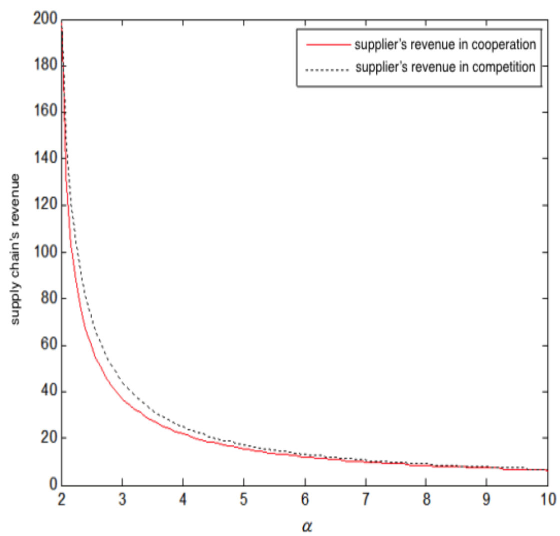

Fig.4 Supply chain's profits change with α

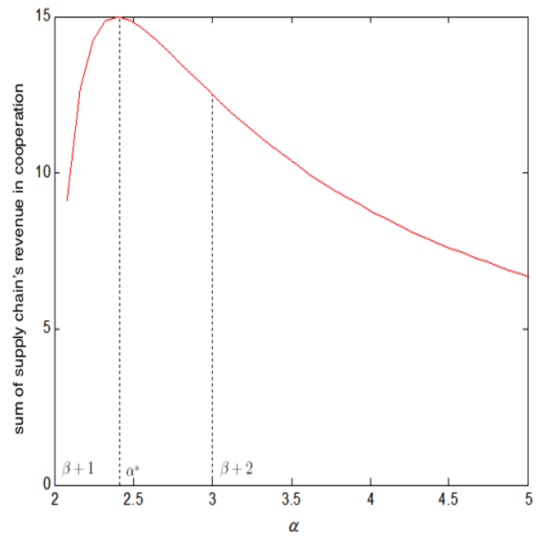

Fig.5 Suppliers' profits change with α *in cooperation case*

Tab.2 The parties' profit of supply chain

	Competition case	Relationship parameters	Corporation case	
$\sum_{i=1}^{2} \pi_S^i$	11.92	<	14.81	π_{ST}^*
π_R^*	59.63	>	44.44	π_{RT}^*
π_T^*	71.55	>	59.25	π_{TT}^*

CONCLUSION

This paper mainly discusses the selection of supplier retailer in supply chain strategy. Based on the retailer dominated supply chain, supplier's revenue has been seriously eroded; therefore, the supplier must seek out relevant strategies to maintain their own benefits. Through the comparative analysis found that, facing the dominant retailer, suppliers can increase their income, select a range of cooperation at the same time, suppliers can also adjust their performance through products to coordinate parameters to achieve their own price elasticity of income increased, which will increase the range (decrease), α or β, when $\alpha < \alpha^*$ ($\alpha > \alpha^*$) or $\beta < \beta^*$ ($\beta > \beta^*$). Therefore, although in the superior position in the supply chain, supplier selection strategy can also be through the optimization to certain domination.

In the process of analysis, we discuss only the supplier selection strategy, but no further discussion on how to prevent the retailer supplier by leading advantages of their cooperation, such as retailer can offer a new contract to have more of their own income, of course. In the future work, we will continue to discuss the retailer leading supply chain exists in the actual operation of the problems, such as the impact of retailer and suppliers, retailer have conflicts of interest abuse of dominant advantage of their own, but also consider the possibility of supplier and retailer cooperation, benefit from the market perspective, we should seek cooperation mechanism and establish leading retailer and suppliers.

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