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Coordination Contracts for Competitive Two Echelon Supply Chain With Price-and-Promotional Effort Dependent Demand

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Abstract

With the deepening of globalization,improve the market share is becoming more and more important,to many enterprises promotional effort is a good choice.Based on price-and-promotional effort dependent demand,we developed a model consists of a dominant manufacture and two retailers,and compared the optimal strategies under the centralized and decentralized scenarios. To coordinate the supply chain and improve the profits of the members of the supply chain, two coordination contracts are proposed, we find that these contracts improved profits of both sides. Finally we validated the effectiveness of these contracts through numerical examples.

Key words: Promotion effort; Price; Demand; Supply chain coordination

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INTRODUCTION

It is important for suppliers and retailers to determine the demand. In reality, there are many factors influence demands. Among them, the effect of price on demand is extensively accepted. However, as the rapid development of economic globalization and market competition, it is urgent to increase the market demand as well, and the most valued of those is the promotion of demand that can raise demand in the market. Both manufacturers and retailers are hoping to get more profits by the promotion of demand. For instance, manufacturers like Coca-Cola and Pepsi-Cola increase market demand for their products by the promotion of demand, and retailers like Suning and Gome increase the market share of product sales by any kinds of promotion mean. Therefore, it is important for us to study on the effect of the market pricing and promotion strategies on the decision made by supply chains and their members.

At present, there have been many scholars carried out many studies about it. For instance, Huang and Li (2001) and Huang et al. (2002) and Li et al. (2002) all discussed the decision problem based on Stackelberg game and Nash equilibrium game as the manufacturer dominate the market, and attempted to redistribute the profit for every supply chain members. In order to coordinate the supply chain, Xie et al. (2009) studied on the optimal pricing and advertising strategy in the single manufacturer and single retailer supply chain. He et al. (2009) considered supply chain contract and coordination problems on the random demand of downstream retailers under the influence of promotion and price. Tsao et al. (2010) studies on multi-level supply chain collaboration under the influence of credit level and efforts in marketing made by retailers. Wang et al. (2011) studied the cooperative advertising model that contains one manufacturer and two retailers in the supply chain under the condition of four possible game.

In existing research, there are a lot of studies about cooperative advertising of manufacturers and retailers and retailers promoting by their own. In this paper, we consider the pricing and promotion problem of a two-tier supply chain composed by a dominant manufacturer and two retailers. In that, demands are not only influenced by price, also depend on the promotion effort of the products. In our model, in order to meet their own demands, the manufacturers promote to improve the overall demand while the two retailers make decisions for their own sales prices. In addition, we also consider coordination of the manufacturers and retailers in the supply chain, so as to attain pareto improvements.

1. PROBLEM DESCRIPTION

Consider a two-tier supply chain composed by a dominant manufacturer and two retailers, in which the manufacturer is the leader while the retailers are the followers and accord to the Nash equilibrium of game between retailers.

Total market size of products made by the manufacturers is $A=A_1+A_2$, in which A_1, A_2 respectively represent market size of retailer 1 and retailer 2. Manufacturers' cost of producing the products is c, who sells products to retailers at wholesale price w, while retailer 1 and retailer 2 respectively sell their products at price p_1 and p_2.Then, the actual demand of retailer 1 and retailer 2 respectively is $D_1=A_1-a_1p_1+\theta p_2$, $D_2=A_2-a_2p_2+\theta p_1$, in which a_1, a_2 represents the actual demand influence coefficient of p_1, p_2 to retailer 1 and retailer 2. θ represents the influence coefficient of cross price between retailers, and $a_1a_2 - \theta^2>0$.

In practice, manufacturers often make promotion by advertising and other means, which raise the overall size of the market, especially in the consumer industry. For instance, P&G and Unilever will invest a lot of money on the advertising to expand the size of the market. We assume that the promotion of manufacturer for their products is $\rho(\rho\geq 1)$, so the overall size of the market will be increased from A to ρA. Because the promotion is intened for the whole market, therefore we assume that the size of the market of retailer 1 and retailer 2 is improved to ρA_1 and ρA_2, and the actual demand of retailer 1&2 will turn into $D_{12}=\rho A_1-a_1p_1+\theta p_2$, $D_{22}=\rho A_2-a_2p_2+\theta p_1$. See Figure 1.

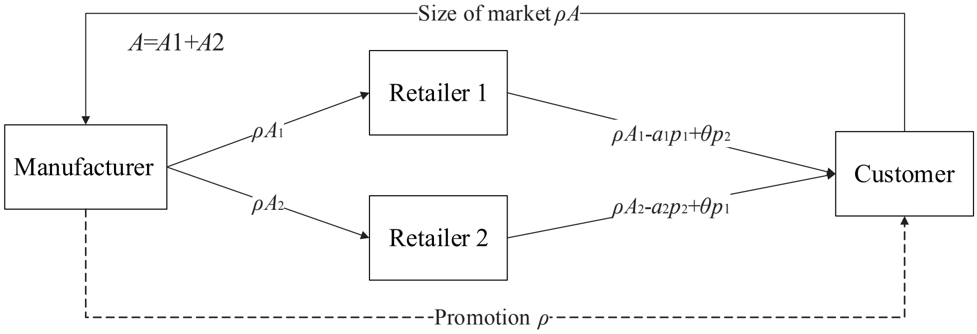

Figure 1
Role of Marketing

And the promotion cost of manufacturer is corresponding to its promotional efforts, we refer to a formula given by Harish (2004) and assume the cost of making promotion is $C(\rho, A)=k(\rho-1)^2$. In which, $k>0$ is a constant and represents attraction to customers, that is, the difficulty of expand the market on the basis of the existing market scale. In addition, we assume that the information for the promotion cost is symmetrical between upstream and downstream.

2. BASIC DECISION MODEL AND THE COORDINATION

2.1 Decentralized Decision Model

In decentralized decision making mode, manufacturers and retailers make decisions according to stackelberg game while the retailers play game with each other according to Nash equilibrium

Manufacturer should determine wholesale prices w of products sold to retailer 1 and retailer 2 and efforts ρ to promote its products; while retailer 1 and retailer 2 should make decisions for their selling prices according to it. As a result, we have to confirm the profit function for each other.

Profit function for manufacturer:

$$\pi_m = (w-c)(D_{12}+D_{22}) - C(\rho, A)$$
$$= (w-c)[\rho(A_1+A_2)+(\theta-a_1)p_1+(\theta-a_2)p_2] - kA(\rho-1)^2 \quad (1)$$

Profit function for retailer 1:

$$\pi_{r1} = (p_1-w)D_{12} = (p_1-w)(\rho A_1 - a_1p_1 + \theta p_2). \quad (2)$$

Profit function for retailer 2:

$$\pi_{r2} = (p_2-w)D_{22} = (p_2-w)(\rho A_2 - a_2p_2 + \theta p_1). \quad (3)$$

2.1.1 Decisions of Retailer

For the possible promotional efforts ρ and wholesale price w decided by manufacturer, retailer 1 and retailer 2 should decide their own optimal sale price p_1 and p_2. Retailer 1 and retailer 2 play game with each other according to Nash equilibrium. Thus, respectively take the first partial derivatives to p_1 and p_2 of Formula (2) and (3) then make it to zero. Below is the simultaneous equations:

$$\begin{cases} \dfrac{\partial \pi_{r1}}{\partial p_1} = \rho A_1 + \theta p_2 + a_1 w - a_1 p_1 = 0 \\ \dfrac{\partial \pi_{r2}}{\partial p_2} = \rho A_2 + \theta p_1 + a_2 w - a_2 p_2 = 0 \end{cases}.$$

To solve the above equations

$$p_1 = \frac{(2a_1a_2 + \theta a_2)w + (2a_2A_1 + \theta A_2)\rho}{4a_1a_2 - \theta^2}, \quad (4)$$

$$p_2 = \frac{(2a_1a_2 + \theta a_1)w + (2a_1A_2 + \theta A_1)\rho}{4a_1a_2 - \theta^2}. \quad (5)$$

Property 1 For retailer 1 and retailer 2, there exists optimal sale price $p_i(i=1,2)$, which maximizes their own profits, and the decision of $p_i(i=1,2)$ is corresponding to the manufacturer's, which meets Formulas (4) and (5).

According to property 1, retail sales price decided by manufacturer is directly proportional to the wholesale price and the promotional efforts are decided by retailers. That is there exist $\frac{\partial p_i}{\partial w} > 0, \frac{\partial p_i}{\partial \rho} > 0$. In addition, the relationship between the sales price and the promotional efforts is affected by the market size of these two retailers.

2.1.2 Decisions of Manufacturer

In decentralization decision-making models, manufacturer dominates, so we analyse manufacturers and retailers by the stackelberg game, that is manufacturer makes decisions for $w$and ρ after considering the possible countermeasures of two retailers. Thus, under this circumstances, we substituted Formulas (4) and (5) into formula (1), get

$$\pi_m(w,\rho) = (w-c)(R_1w + R_2\rho) - kA(\rho-1)^2. \quad (6)$$

In that, $R_1 = \frac{(a_1+a_2)\theta^2 + 2a_1a_2\theta - 2a_1a_2(a_1+a_2)}{4a_1a_2 - \theta^2}$,

$$R_2 = \frac{2a_1a_2A + (a_1A_2 + a_2A_1)\theta}{4a_1a_2 - \theta^2}.$$

Take the first partial derivatives to w and ρ of Formula (6) then make it to zero, simultaneously solving the equation and get

$$\rho^{sb} = \frac{4kAR_1 - cR_1R_2}{4kAR_1 + R_2^2}, \quad w^{sb} = \frac{2ckAR_1 + cR_2^2 - 2kAR_2}{4kAR_1 + R_2^2}.$$

Property 2: If $4kAR_1 + R_2^2 < 0$ is met, w^{sb} and ρ^{sb} that is solved is the manufacturer's optimal decision.

Pr.: by a_1a_2-θ^2>0.

Attain

$$(a_1+a_2)\theta^2 + 2a_1a_2\theta - 2a_1a_2(a_1+a_2) < 2a_1a_2\sqrt{a_1a_2}$$

$-a_1a_2(a_1+a_2) < 0$, that is R_1<0.

$$\frac{\partial \pi_m(w,\rho)}{\partial w} = 2R_1w + R_2\rho - cR_1,$$

$$\frac{\partial \pi_m(w,\rho)}{\partial \rho} = (w-c)R_2 - 2kA(\rho-1),$$

$$\frac{\partial^2 \pi_m(w,\rho)}{\partial w^2} = 2R_1 < 0, \frac{\partial^2 \pi_m(w,\rho)}{\partial w \partial \rho} = R_2,$$

$$\frac{\partial^2 \pi_m(w,\rho)}{\partial \rho^2} = -2kA < 0.$$

To find optimal solution of the function,，it must exist $-4kAR_1 - R_2^2 > 0$, that is $4kAR_1 + R_2^2 < 0$.Q.E.D.

Then, if property 2 is met, under the decentralized circumstances, the optimal sale price decided by retailer 1 and retailer 2 is respectively:

$$p_1^{sb} = \frac{(2a_1a_2 + \theta a_2)w^{sb} + (2a_2A_1 + \theta A_2)\rho^{sb}}{4a_1a_2 - \theta^2},$$

$$p_2^{sb} = \frac{(2a_1a_2 + \theta a_1)w^{sb} + (2a_1A_2 + \theta A_1)\rho^{sb}}{4a_1a_2 - \theta^2}.$$

Thus, we can easily see, when retailer 1 and retailer 2 make decision for their selling prices, they not only affected by the price-interaction-influence demand coefficient between retailers, but also associated with the price-influence demand coefficient of other retailers; meanwhile, the selling price is also associated with the market size of both sides. Besides, it is notable that the decisions of making selling price interaction between the retailers.

Under this circumstances, the actual demand and promotional cost of retailer 1, retailer 2 and manufacturer are:

$$D_{12}^{sb} = \frac{(a_1a_2\theta + a_1\theta^2 - 2a_1^2a_2)w^{sb} + (2a_1a_2A_1 + a_1A_2\theta)\rho^{sb}}{4a_1a_2 - \theta^2},$$

$$D_{22}^{sb} = \frac{(a_1a_2\theta + a_2\theta^2 - 2a_1a_2^2)w^{sb} + (2a_1a_2A_2 + a_2A_1\theta)\rho^{sb}}{4a_1a_2 - \theta^2},$$

$$D^{sb} = \frac{[2a_1a_2\theta + (a_1+a_2)\theta^2 - 2a_1a_2(a_1+a_2)]w^{sb} + [2a_1a_2A + (a_1A_2 + a_2A_1)\theta]\rho^{sb}}{4a_1a_2 - \theta^2}$$

$$C(\rho^{sb}, A) = kA(\rho^{sb}-1)^2.$$

Respectively, the optimal profit corresponding to retailer 1, retailer 2 and manufacturer are:

$$\pi_{r1}^{sb} = (p_1 - w)D_{12}^{sb}, \quad \pi_{r2}^{sb} = (p_2 - w)D_{22}^{sb}, \quad \pi_m^{sb} = (w^{sb} - c)Q^{sb} - C(\rho^{sb}, A).$$

2.2 Centralized Decision Model

In centralized mode, the manufacturer and two retailers are regarded as a whole to make decisions. That is, to maximize the profit of the supply chain by the overall decision. Under this circumstances, the whole supply chain need to make decisions for the sales prices p_1, p_2 and the promotion ρ. Thus, in the first we must determine the profit function π of the supply chain.

$$\pi=(p_1-c)D_{12}+(p_2-c)D_{22}-kA(\rho-1)^2. \tag{7}$$

We take the first partial derivatives to p_1, p_2 and ρ of Formula (7) then make it to zero, forming a formula includes three equations, and obtain:

$$\begin{cases} 2a_1p_1-2\theta p_2-\rho A_1=(a_1-\theta)c \\ 2a_2p_2-2\theta p_1-\rho A_2=(a_2-\theta)c \\ A_1p_1+A_2p_2-2kA\rho=(c-2k)A \end{cases}.$$

Solve the above formula and obtain the optimal profit and promotion under this circumstances:

$$\rho^{fb}=\frac{(c-4k)(a_1a_2-\theta^2)A}{a_2A_1^2+a_1A_2^2+2\theta A_1A_2-4kA(a_1a_2-\theta^2)},$$

$$p_1^{fb}=\frac{c}{2}+\frac{(a_2A_1+\theta A_2)}{2a_1a_2-2\theta^2}\rho^{fb}, \tag{8}$$

$$p_2^{fb}=\frac{c}{2}+\frac{(a_1A_2+\theta A_1)}{2a_1a_2-2\theta^2}\rho^{fb}. \tag{9}$$

Property 3: Under centralized decision-making situations, the sales price and the promotion is linearly related, which meet Formulas (8) and (9). Under this circumstances, the demands and promotion costs of retailers 1&2 and manufacturers are:

$$D_{12}^{fb}=\frac{A_1}{2}\rho^{fb}-\frac{(a_1-\theta)c}{2},$$

$$D_{22}^{fb}=\frac{A_2}{2}\rho^{fb}-\frac{(a_2-\theta)c}{2},$$

$$D^{fb}=\frac{A}{2}\rho^{fb}-\frac{(a_1+a_2-2\theta)c}{2},$$

$$C(\rho^{fb},A)=kA(\rho^{fb}-1)^2.$$

Then, corresponding optimal profit of supply chain is:

$$\pi^{fb}=(p_1^{fb}-c)D_{12}^{fb}+(p_2^{fb}-c)D_{22}^{fb}-C(\rho^{fb},A).$$

2.3 Supply Chain Coordination

Under centralized decision-making situation, the overall profit is $\pi^{fb}=(p_1^{fb}-c)D_{12}fb+(p_2^{fb}-c)D_{22}^{fb}-C(\rho^{fb},A)$; while under decentralized decision-making situatiton, the sum of the profit π_{r1}^{sb} of retailer 1, the profit π_{r2}^{sb} of retailer 2 and the profit π_m^{sb} of manufacturer is $\pi_{r1}^{sb}+\pi_{r2}^{sb}+\pi_m^{sb}=(p_1^{sb}-c)D_{12}^{sb}+(p_2^{sb}-c)D_{22}^{sb}-C(\rho^{fb},A)$. From above, it is easy to see that $\pi^{fb}\geq\pi_{r1}^{sb}+\pi_{r2}^{sb}+\pi_m^{sb}$, that is, overall profit under centralized decision-making situation is greater than the sum of the profits of retailers and manufacturer under decentralized decision-making situation, which make room for manufacturers to cooperate with retailers to increase their profits. In other words, profits of each party are not less than the optimal profits π_{r1}^{sb}, π_{r2}^{sb} and π_m^{sb} made by retailers and manufacturer under decentralized decision-making situation. Because the increased profits are acquired by manufacturer with demands promotion, it requires manufacturers pay more promotion cost. Then, in order to retailers 1&2 should give certain promotional subsidies to encourage manufacturers to intensify the promotion.

2.3.1 The Wholesale Price Incentives

In order to encourage manufacturer make decisions according to promotion under centralized-decision situations, we assume that retailer 1 and retailer 2 have given certain wholesale price incentives to manufacturer respectively, that is, improving the wholesale price to γ_1 and γ_2 times, while the selling price of retailers are p_1^{fb} and p_2^{fb} and the wholesale price of manufacturer is turned into γ_1w^{sb} and γ_2w^{sb}. At this time,the profits of each party are:

$$\pi_{r1}'=(p_1^{fb}-\gamma_1w^{sb})D_{12}^{fb},\quad \pi_{r2}'=(p_2^{fb}-\gamma_2w^{sb})D_{22}^{fb}$$
$$\pi_m^{sb}=(\gamma_1w^{sb}-c)D_{12}^{fb}+(\gamma_2w^{sb}-c)D_{22}^{fb}-C(\rho^{sb},A).$$

And it is required to meet:

$$\begin{cases} (p_1^{fb}-\gamma_1w^{sb})D_{12}^{fb}\geq\pi_{r1}^{sb} \\ (p_2^{fb}-\gamma_2w^{sb})D_{22}^{fb}\geq\pi_{r2}^{sb}. \\ (\gamma_1w^{sb}-c)D_{12}^{fb}+(\gamma_2w^{sb}-c)D_{22}^{fb}-kA(\rho^{fb}-1)^2\geq\pi_m^{sb} \end{cases}$$

Solve the above inequity and attain:

$$\frac{\pi_m^{sb}+kA(\rho^{fb}-1)^2+cD^{fb}}{w^{sb}D_{12}^{fb}}-\frac{D_{22}^{fb}}{D_{12}^{fb}}\gamma_2\leq\gamma_1\leq\frac{p_1^{fb}D_{12}^{fb}-\pi_{r1}^{sb}}{w^{sb}D_{12}^{fb}},$$

$$\frac{\pi_m^{sb}+kA(\rho^{fb}-1)^2+cD^{fb}}{w^{sb}D_{22}^{fb}}-\frac{D_{12}^{fb}}{D_{22}^{fb}}\gamma_1\leq\gamma_2\leq\frac{p_2^{fb}D_{22}^{fb}-\pi_{r2}^{sb}}{w^{sb}D_{22}^{fb}}.$$

From the above relations, it is easy for us to see that there are links between γ_1 and γ_2 determined by retailer 1 and retailer 2, which is exactly conformed to reality. Some retailers give wholesale price support to manufacturer and it will influence the others'. For retailer 1 and retailer 2, when γ_1 and γ_2 take values in the above range, under the condition which can maximize the profits of the whole supply chain, the profits of each party are not less at least.

For retailers 1 and retailers 2, when and where within the range values, can make the whole supply chain profit maximization under the condition of the profits at least worse.

2.3.2 Promotion Cost-Sharing

The cost of manufacturer will raise as the promotional improvement and this part of cost should be compensated. We assume that the wholesale prices of manufacturer maintains the levels as is under decentralized decision-making situations, and the proportion of retailer 1 and retailer 2 shares the costs is λ_1 and λ_2 respectively. At this time, the promotion and the wholesale price levels decided by manufacturer is ρ^{fb} and w^{sb}, while the selling price of retailer 1 and retailer 2 are ρ_1^{fb} and ρ_2^{fb}.At this point, the profits of each party are:

$$\pi_{r1}{}'' = (p_1{}^{fb} - w^{sb})D_{12}{}^{fb} - \lambda_1 C(\rho^{sb}, A)\,,\quad \pi_{r2}{}'' = (p_1{}^{fb} - w^{sb})D_{22}{}^{fb} - \lambda_2 C(\rho^{sb}, A)\,,$$

$$\pi_m{}^{sb} = (w^{sb} - c)D^{fb} - (1 - \lambda_1 - \lambda_2)C(\rho^{sb}, A)\,.$$

And it is required to meet:

$$\begin{cases} (p_1{}^{fb} - w^{sb})D_{12}{}^{fb} - \lambda_1 kA(\rho^{fb} - 1)^2 \ge \pi_{r1}{}^{sb} \\ (p_2{}^{fb} - w^{sb})D_{22}{}^{fb} - \lambda_2 kA(\rho^{fb} - 1)^2 \ge \pi_{r2}{}^{sb} \\ (w^{sb} - c)D^{fb} - (1 - \lambda_1 - \lambda_2)kA(\rho^{fb} - 1)^2 \ge \pi_m{}^{sb} \end{cases}.$$

Solve the above inequity and attain

$$\frac{\pi_m{}^{sb} + kA(\rho^{fb} - 1)^2 - (w^{sb} - c)D^{fb}}{kA(\rho^{fb} - 1)^2} - \lambda_2 \le \lambda_1 \le \frac{(p_1{}^{fb} - w^{sb})D_{12}{}^{fb} - \pi_{r1}{}^{sb}}{kA(\rho^{fb} - 1)^2}\,,$$

$$\frac{\pi_m{}^{sb} + kA(\rho^{fb} - 1)^2 - (w^{sb} - c)D^{fb}}{kA(\rho^{fb} - 1)^2} - \lambda_1 \le \lambda_2 \le \frac{(p_2{}^{fb} - w^{sb})D_{22}{}^{fb} - \pi_{r2}{}^{sb}}{kA(\rho^{fb} - 1)^2}.$$

From the above relations, it is easy for us to see that there are links between λ_1 and λ_2 determined by retailer 1 and retailer 2, that is, the promotion cost shared by some retailers, which will influence the level of the cost shared by other retailers. For retailer 1 and retailer 2, when λ_1 and λ_2 take values in the above range, under the condition which can maximize the profits of the whole supply chain, the profits of each party are not less at least.

3. CALCULATING-EXAMPLES ANALYSIS

According to the above analysis, we can get the decisions and results under three different situations. Thus, we use the following instance data to simulate. Assume that the overall market size of the product made by manufacturer is 30, in that the market share of retailer 1 and retailer 2 are 20 and 10 respectively. It is known that demands of retailers are influenced by its own selling price, the selling price of its competitors and the promotion of the manufacturer, in that the actual demand of retailer *i is* $D_{i2}=\rho A_i - a_i p_i + \theta p_j$, $a_1=2$, $a_2=1$, $\theta=0.5$. For the manufacturer, the function of promotion cost is $C(\rho, A)=150(\rho-1)^2$.

By the above data, we choose the values of γ_1 and γ_2 are 1.8 and 2; while the values of λ_1 and λ_2 are 0.35 and 0.2. Calculating the decisions and results of each party, we find that the actual demand of the market is raised from 14.40096 to 54.7 after we make the coordination, which increases the demands indeed. The specific results are shown in Table 1.

Is calculated in three cases of the parties to the decision-making and as a result, we found that the real needs of the market after coordination greatly increased from 14.40096 to 54.7, really achieve the growth of demand, the specific results are shown in Table 1:

Table 1
Calculating-Examples Analysis Under Three Different Situations

Situations	p_1^*	p_2^*	w^*		ρ^*	π_{r1}	π_{r2}	π_m	π
Decentralization	18.19221	20.21356	14.06567		1.726535	34.05658	37.79656	94.57928	166.4324
Centralization	28	33.4	----		3.78	----	----	----	362.3
Coordination	28	33.4	25.31821	28.13134	3.78	97.34912	96.94334	168.0075	362.3
	28	33.4	14.06567		3.78	100.0752	123.8997	138.3252	362.3

It is easy to find that the profit of the whole supply chain is not only raised after coordination, but also the profits of each party are improved greatly, which indeed achieves the coordination of the supply chain.

CONCLUSION

As to the cooperation game model that there are a single manufacturer and two retailers, we consider the influence of the manufacturer promotion and retailer pricing. We solve this problem under the situation that accord to stackelberg game between manufacturer and retailers and accord to Nash equilibrium between retailers and find that the profits of the supply chain in under this case are less than making decisions regard the supply as a whole part. Therefore, we consider three-sides collaboration of the two kinds of situations: One is manufacturer improves its promotional efforts while each of retailer subsidizes manufacturer based on wholesale price, the other is manufacturer improve the promotion while retailers subsidize the promotional cost. We find that in the certain range of wholesale pricing subsidy and promotion cost-sharing, we can achieve the goal of the coordination of the retailers and manufacturer in the supply chain to improve their profits.

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