

## Competition and Coordination for the Dual-channel Supply Chain with Channel Preference

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### Abstract

*Aiming at the dual-channel supply chain system with the manufacturer owned direct channel and retail channel simultaneously, the consumers are divided into retail channel loyalty and brand loyalty two parts, under the condition of market demand are depend on the consumers' channel preference, we studied to the pricing game and coordination between the manufacturer and retailer. The research result showed that the Nash equilibrium of price exists in centralized and decentralized supply chain system, the channel preference degree of consumers, the number of brand loyalty consumers are all have certain influence on supply chain's optimal pricing strategy, and the price markup contract can realize the coordination of supply chain. The numerical experiment has showed the effectiveness of the conclusions.*

**Keywords:** channel preference; supply chain; competition; coordination.

### 1. Introduction

With the rapid development of e-commerce and the third-part logistics, more and more brand manufacturers have began to set up direct sales by introducing internet channel. It can put manufacturers in direct touch with consumers, and master the first-hand information of market demand, so they can know the market better. Many well-known enterprises, such as IBM, HP, Estee Lauder, and so on, are all obtained a great success by adopting the dual-channel marketing strategy. But the introduce of internet direct sales channel also give rise to the benefit game and channel conflict between manufacturer and retailer, and consequently lower the efficiency of supply chain, Webb pointed out that product pricing is the primary factor of channel conflict, so the pricing strategy is an important issue of dual-channel supply chain[1-5].

Presently, there have some research results on the channel preference of consumers. Wang Weiguang *et al*[6] studied the pricing and coordination problem of dual-channel supply chain on the basis of considering the consumers' channel preference degree; Wang Zhihong *et al*[7] studied the manufacturer's pricing strategy and channel design and selection when the market demand is related to the consumers' channel preference; Kuiran Shi *et al*[8] considered the influence of manufacturer and retailer's altruistic behaviour on the channel's pricing strategy on the basis of consumer's channel preference; Moutaz Khouja *et al*[9] studied the manufacturer's channel selection and pricing problem under the condition that channel preference affects the market demand. Li Li *et al*[10] studied the inventory policy of dual-channel supply chain under the condition of consumer's channel preference.

Different to the above mentioned document researches; the paper considers the more intensive market model of consumers: a portion of consumers only buy products from retail channel, denotes the consumers' channel preference behaviour by demand function,

and studies the competition and coordination of dual-channel supply chain under the condition of consumers' channel preference.

## 2. Model Description

A dual-channel supply chain with a single product, and composed of one risk neutral manufacturer and one risk neutral retailer is examined in this paper, the consumers can be divided into two types: the one is retail store loyalty; the other is product brand loyalty. The consumers of retail store loyalty only buy products from retail channel; while the consumers of product brand loyalty will consider buy products from retail and direct channel (see Fig.1). the retailer's retail price is  $P_r$ , and the manufacturer sells the products to end customers directly at direct sale price  $P_d$ , the manufacturer sells the products to the retailer at wholesale price  $w$ , the number of retail store loyalty consumers is  $\alpha_r$ , and the number of product brand loyalty consumers is  $\alpha_m$ , the unit product cost of manufacturer sales from retail channel is  $c_r$ , and the unit product cost of manufacturer sales from direct channel is  $c_d$ , consumer  $J$ 's willingness to pay the product  $v_j$  is a random variable, and  $v_j \sim U(0,1)$ .  $\xi_j$  is the consumer  $J$ 's preference degree to retail channel with respect to direct channel, and  $\xi_j \sim U(a,b)$ , where  $-1 < a < 0$ ,  $0 < b < 1$ .

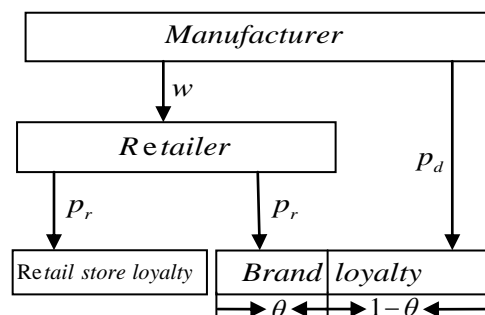


Figure 1. The Dual-channel Supply Chain Model

## 3. Model Construction

When the consumer buy products, firstly the consumer will choose the purchase channel according to its channel preference, and then decide whether to buy the product or not according to the consumer surplus, the consumer will buy the product as long as its consumer surplus is large than 0. For the product brand loyalty consumers, it will firstly consider in which channel to buy the product according to the size of  $P_r - P_d$  and  $\xi_j$ , when  $P_r - P_d \geq \xi_j$ , consumer  $J$  will consider buy the product in direct channel, when  $P_r - P_d < \xi_j$ , consumer  $J$  will consider buy the product in retail channel. Then if consumer  $J$  consider buy the product in direct channel, and  $v_j \geq P_d$ , consumer  $J$  will buy the product, otherwise, consumer  $J$  will not buy the product; if consumer  $J$  consider buy the product in retail channel, and  $v_j \geq P_r$ , consumer  $J$  will buy the product, otherwise, consumer  $J$  will not buy the product. Actually, as for the product brand loyalty consumers, the portion of consumers which buy products in two channel can be determined by the relative size of  $P_r$  and  $P_d$ , the portion of consumers which buy products in retail channel:

$$\theta = \frac{E(X_1 + X_2 + \dots + X_{\alpha_m})}{\alpha_m} = \frac{\sum_{j=1}^{\alpha_m} P(P_r - P_d \leq \xi_j)}{\alpha_m} = \frac{\alpha_m P(P_r - P_d \leq \xi_j)}{\alpha_m} = P(P_r - P_d \leq \xi_j)$$

(1)

That is

$$\theta = \begin{cases} 1, & p_r - p_d \leq a \\ \frac{b - (p_r - p_d)}{b - a}, & a < p_r - p_d < b \\ 0, & p_r - p_d \geq b \end{cases} \quad (2)$$

According to the actual background of dual-channel supply chain, we can leave out the condition of brand loyalty consumers only buy products from retail channel or direct

channel, that is to say,  $\theta = \frac{b - (p_r - p_d)}{b - a}$ . In order to simplified calculation, similarly to Moutaz Khouja<sup>[9]</sup>, it is assumed that  $\alpha_r + \alpha_m = 1$ . So we can get the product demand function of retail store loyalty consumers:

$$Q_{r1} = \begin{cases} \alpha_r(1 - p_r), & 0 \leq p_r < 1 \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

The demand functions of brand loyalty consumers in retail channel  $Q_{r2}$  and direct channel  $Q_d$  are given by

$$Q_{r2} = \begin{cases} (1 - p_r)\theta\alpha_m, & 0 \leq p_r < 1 \\ 0, & \text{otherwise} \end{cases} \quad (4)$$

$$Q_d = \begin{cases} (1 - p_d)(1 - \theta)\alpha_m, & 0 \leq p_d < 1 \\ 0, & \text{otherwise} \end{cases} \quad (5)$$

respectively.

### 3.1. The Centralized Dual-channel Supply Chain

In the centralized dual-channel supply chain, the supply chain's profit function  $\pi_c$  is given by

$$\pi_c = (p_r - c_r)(Q_{r1} + Q_{r2}) + (p_d - c_d)Q_d \quad (6)$$

In order to calculate conveniently, it is assumed that  $p_r - p_d = \delta$ , so  $a < \delta < b$ , as  $\theta = \frac{b - (p_r - p_d)}{b - a} = \frac{b - \delta}{b - a}$ , therefore we can use  $\delta$  directly to reflect the consumers' channel preference. Analysis the supply chain's profit function, we have the following theorem:

**Theorem 1.** In the centralized dual-channel supply chain with consumers' channel preference, the supply chain's optimal pricing strategy are given by

$$p_{rc}^* = \frac{1 + c_r}{2} + \frac{\alpha_m(\delta - a)(c_d - c_r + 2\delta)}{2(b - a)} \quad (7)$$

$$p_{dc}^* = \frac{1 + c_r}{2} + \frac{\alpha_m(\delta - a)(c_d - c_r + 2\delta)}{2(b - a)} - \delta \quad (8)$$

**Proof:** As  $p_r - p_d = \delta$ , so  $p_r = p_d + \delta$ , substituting (3), (4), (5) and  $p_r = p_d + \delta$  into (6),

and  $\frac{\partial^2 \pi_c}{\partial p_r^2} = -2 < 0$ ,  $\frac{\partial \pi_c}{\partial p_r} = 0$ , therefore, there exists maximum on  $\pi_c$ , and by  $\frac{\partial \pi_c}{\partial p_r} = 0$ , we

can obtained formula (7), then according to  $p_d = p_r - \delta$ , formula (8) is obtained.

Then the total profit of supply chain

$$\pi_c^* = (p_{rc}^* - c_r)[\alpha_r(1 - p_{rc}^*) + (1 - p_{rc}^*)\theta\alpha_m] + (p_{dc}^* - c_d)(1 - p_{dc}^*)(1 - \theta)\alpha_m,$$

Analyzed the optimal pricing strategy of centralized supply chain and draw the following conclusions:

**Proposition 1.** The effect of consumers' channel preference on the manufacturer and retailer's pricing decision is given by

$$\frac{\partial p_{rc}^*}{\partial \delta} > 0, \quad \frac{\partial p_{dc}^*}{\partial \delta} < 0$$

It is observed from proposition 1 that the greater of consumers' retail channel preference, the higher of traditional retail channel pricing, and the lower of direct channel pricing.

**Proposition 2.** The number of brand loyalty consumers' effect on the manufacturer and retailer's pricing decision is given by

$$\frac{\partial p_{rc}^*}{\partial \alpha_m} = \frac{\partial p_{dc}^*}{\partial \alpha_m} > 0$$

Proposition 2 showed that the number of brand loyalty consumers are all have influence on the manufacturer and retailer's pricing decision, and the larger number of brand loyalty consumers, the higher of retail and direct channel pricing.

### 3.2. The Decentralized Dual-channel Supply Chain

In the decentralized dual-channel supply chain, the retailer and manufacturer maximize their own profits respectively, the paper models the decision as a sequential, Stackelberg game, with the manufacturer as the leader and the retailer as the follower, then the manufacturer and retailer's profit are

$$\pi_m = (w - c_r)(Q_{r1} + Q_{r2}) + (p_d - c_d)Q_d \tag{9}$$

$$\pi_r = (p_r - w)(Q_{r1} + Q_{r2}) \tag{10}$$

respectively.

Similarly, it is assumed that  $p_r - p_d = \delta$ , Analysis the manufacturer and retailer's profit function, we have the following theorem:

**Theorem 2.** In the decentralized dual-channel supply chain with consumers' channel preference, the supply chain's optimal pricing strategy are given by

$$w^* = \frac{\alpha_m c_d + \alpha_r (1 + c_r) + 2\alpha_m \delta}{1 + \alpha_r} + \frac{\alpha_m (b - \delta)(1 + c_r - 2c_d - 4\delta)}{(1 + \alpha_r)[2b - \alpha_m \delta - a(1 + \alpha_r)]} \tag{11}$$

$$p_r^* = \frac{\alpha_m c_d + \alpha_r (2 + c_r) + 2\alpha_m \delta + 1}{2(1 + \alpha_r)} + \frac{\alpha_m (b - \delta)(1 + c_r - 2c_d - 4\delta)}{2(1 + \alpha_r)[2b - \alpha_m \delta - a(1 + \alpha_r)]} \tag{12}$$

$$p_d^* = \frac{\alpha_m c_d + \alpha_r (2 + c_r) - 4\alpha_r \delta + 1}{2(1 + \alpha_r)} + \frac{\alpha_m (b - \delta)(1 + c_r - 2c_d - 4\delta)}{2(1 + \alpha_r)[2b - \alpha_m \delta - a(1 + \alpha_r)]} \tag{13}$$

**Proof:** The inverse order method is used to solve the Stackelberg equilibrium solution of supply chain system. Firstly, given the manufacturer's direct channel price  $p_d$  and wholesale

price  $w$ , as  $\frac{\partial^2 \pi_r}{\partial p_r^2} = -2\alpha_r - \frac{2\alpha_m (b - \delta)}{b - a} < 0$ , so there exists maximum on  $\pi_r$ , and then by  $\frac{\partial \pi_r}{\partial p_r} = 0$ , we have  $p_r = \frac{1 + w}{2}$ .

Substituting  $p_r = \frac{1+w}{2}$ ,  $p_d = p_r - \delta$  into (9), and as  $\frac{\partial^2 \pi_m}{\partial w^2} = -\frac{(\delta-a)(\alpha_r-1)}{2(a-b)} - 1 < 0$ ,

therefore, there exists maximum on  $\pi_m$ , and then by  $\frac{\partial \pi_m}{\partial w} = 0$ , we obtained formula (11).

Substituting (9) into  $p_r = \frac{1+w}{2}$  and  $p_d = p_r - \delta$ , and can obtained (12) and (13).

Then the profit of the manufacturer and retailer are

$$\pi_m^* = (w^* - c_r)[\alpha_r(1 - p_r^*) + (1 - p_r^*)\theta\alpha_m] + (p_d^* - c_d)(1 - p_d^*)(1 - \theta)\alpha_m \quad (14)$$

$$\pi_r^* = (p_r^* - w^*)[\alpha_r(1 - p_r^*) + (1 - p_r^*)\theta\alpha_m] \quad (15)$$

respectively.

Analyzed the optimal pricing strategy of decentralized supply chain and draw the following conclusions:

**Proposition 3.** The effect of consumers' channel preference on the manufacturer and retailer's pricing decision is given by

$$\frac{\partial p_r^*}{\partial \delta} = \frac{1}{2} \frac{\partial w^*}{\partial \delta} > 0, \quad \frac{\partial p_d^*}{\partial \delta} < 0$$

It can be seen that consumers' channel preference are all have influence on the manufacturer and retailer's pricing decision, and the larger of consumers' channel preference to retail channel, the higher of retail channel pricing, and the higher of manufacturer's wholesale price to retailer, and the lower of direct channel pricing. And

the change rate of retailer's optimal pricing with the consumers' channel preference is  $\frac{1}{2}$  times for the change rate of manufacturer's unit product wholesale price to retailer with the consumers' channel preference.

**Proposition 4.** The number of brand loyalty consumers' effect on the manufacturer and retailer's pricing decision is given by

$$\frac{\partial p_r^*}{\partial \alpha_m} = \frac{\partial p_d^*}{\partial \alpha_m} = \frac{1}{2} \frac{\partial w^*}{\partial \alpha_m} < 0$$

Proposition 4 showed that the number of brand loyalty consumers are all have influence on the manufacturer and retailer's pricing decision, and the larger number of brand loyalty consumers, the lower of retail and direct channel pricing, and the lower of manufacturer's unit product wholesale price to retailer. And the change rate of retailer's optimal pricing with the number of brand loyalty consumers is the same as the change rate

of manufacturer's optimal pricing with the number of brand loyalty consumers; it is  $\frac{1}{2}$  times for the change rate of manufacturer's unit product wholesale price to retailer with the number of brand loyalty consumers.

#### 4. The Supply Chain Coordination

From theorem1 and theorem 2, we know that  $p_r^* \neq p_{rc}^*$ , so the decentralized supply chain is low efficiency, this section we consider the price markup contract, we make great efforts to the total profit of manufacturer and retailer reaches the total profit level of centralized one, and at the same time, the profits of manufacturer and retailer get a Pareto improvement. Then we have the following theorem:

**Theorem 3.** There exist the added value  $l_1$  and reduced value  $l_2$  of price to coordinate the supply chain.

**Proof:** it is assumed that  $l_1 - l_2 = p_c^* - p^*$ , and assumed that under the price markup contract, the profit of manufacturer and retailer are  $\pi_m^{**}$  and  $\pi_r^{**}$ , respectively. Then we have

$$\begin{aligned} \pi_m^{**} - \pi_m^* &= (w^* + l_1 - c_r)[\alpha_r(1 - p_{rc}^*) + (1 - p_{rc}^*)\theta\alpha_m] + (p_{dc}^* - c_d)(1 - p_{dc}^*)(1 - \theta)\alpha_m \\ &\quad - (w^* - c_r)[\alpha_r(1 - p_r^*) + (1 - p_r^*)\theta\alpha_m] + (p_d^* - c_d)(1 - p_d^*)(1 - \theta)\alpha_m \\ \pi_r^{**} - \pi_r^* &= (p_{rc}^* - w^* - l_1)[\alpha_r(1 - p_{rc}^*) + (1 - p_{rc}^*)\theta\alpha_m] - (p_r^* - w^*)[\alpha_r(1 - p_r^*) + (1 - p_r^*)\theta\alpha_m] \end{aligned}$$

It is observed that  $\pi_m^{**} - \pi_m^*$  and  $\pi_r^{**} - \pi_r^*$  are increase and decrease on  $l_1$ , respectively, and  $\pi_m^{**} + \pi_r^{**} \geq \pi_m^* + \pi_r^*$ , therefore, there surely exist  $l_1$ , such that  $\pi_m^{**} > \pi_m^*$ , and  $\pi_r^{**} > \pi_r^*$ . And then according to  $l_1 - l_2 = p_c^* - p^*$ , we can find  $l_2$ . So there exist the added value  $l_1$  and reduced value  $l_2$  of price to coordinate the supply chain.

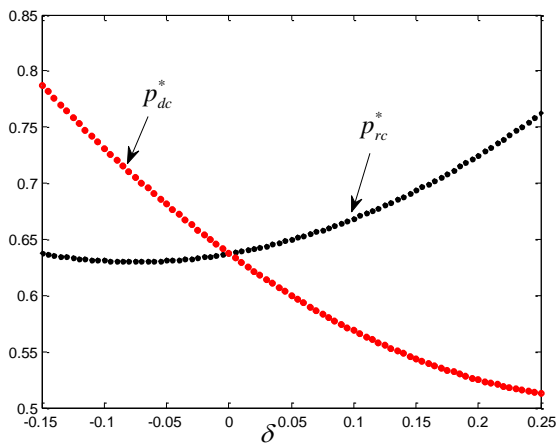
### 5. Numerical Examples

According to the theoretical analysis above, it is showed that the consumers' channel preference and the number of brand loyalty consumers have an important impact on the optimal pricing decisions of supply chain members. Hereby we present some numerical examples to illustrate the effect of consumers' channel preference and the number of brand loyalty consumers on the optimal pricing decisions for the dual-channel supply chain.

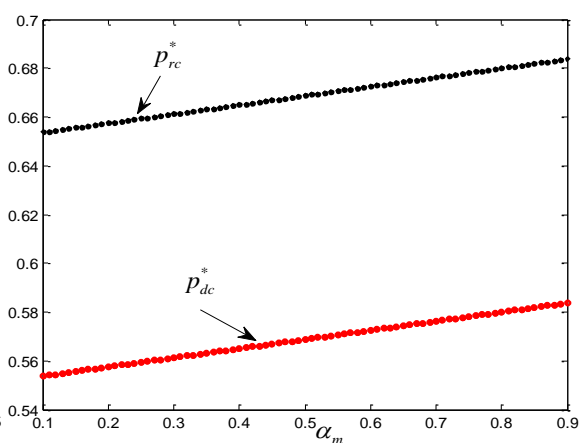
In the following example, the parameters in the dual-channel supply chain take in the following values:

$$\alpha_r = 0.3, c_r = 0.3, c_d = 0.2, b = 0.2, a = -0.2.$$

The relationship of consumers' channel preference and the number of brand loyalty consumers and the optimal pricing of manufacturer and retailer in centralized supply chain is as Figure 2 and Figure 3, they are consistent with the theoretical results mentioned in proposition 1 and proposition 2.



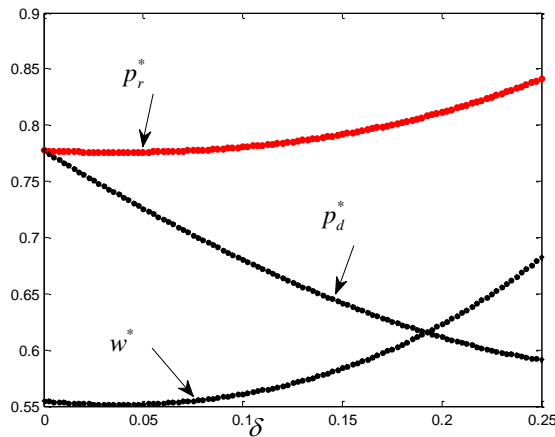
**Figure 2. The Influence of  $\delta$  on the Centralized Supply Chain's Optimal Pricing**



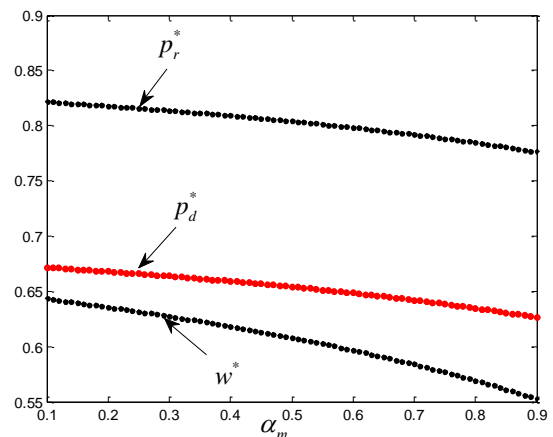
**Figure 3. The Influence of  $\alpha_m$  on the Centralized Supply Chain's Optimal Pricing**

The relationship of consumers' channel preference and the number of brand loyalty consumers and the optimal pricing of manufacturer and retailer in the decentralized

supply chain is as Figure 4 and Figure 5, they are consistent with the theoretical results mentioned in proposition 3 and proposition 4.

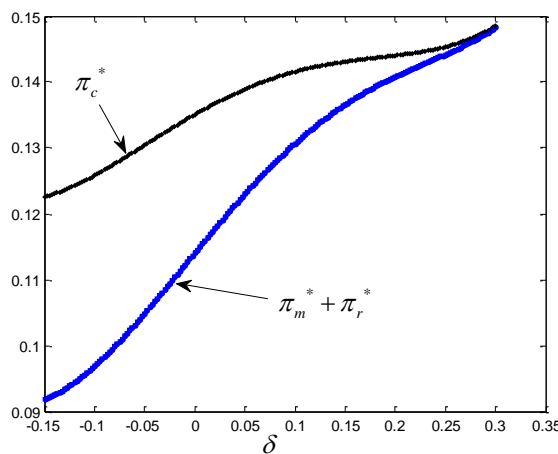


**Figure 4. The Influence of  $\delta$  on the Decentralized Supply Chain's Optimal Pricing**

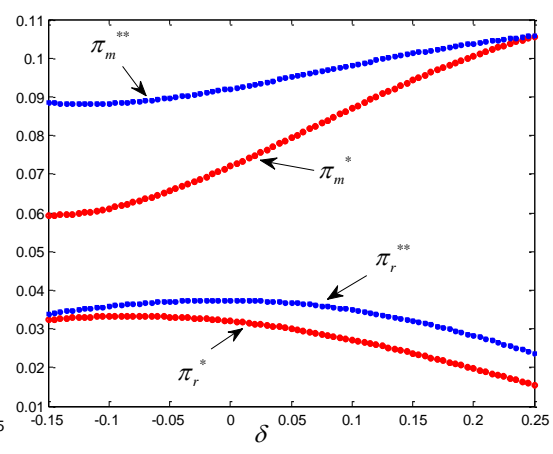


**Figure 5. The Influence of  $\alpha_m$  on Decentralized Supply Chain's Optimal Pricing**

The total profit of decentralized and centralized supply chain is as Figure 6. it is observed from Figure 6 that the total profit in centralized supply chain is greater than the decentralized supply chain, and with the increasing of  $\delta$ , the supply chain's total profit also increasing, and the difference between the total profit in decentralized and the centralized supply chain is gradually decrease. It mainly because the consumers prefer the lower price of direct channel, and the direct channel attracts the more consumers because of lower price, while the consumers in retail channel have certain loyalty, the retailer can also obtain the more profit by improving the unit product pricing.



**Figure 6. The Influence of  $\delta$  on the Centralized and Decentralized Supply Chain's Total Profit**



**Figure 7. The Influence of  $\delta$  on the Manufacturer and Retailer's Profit under Contract Coordination**

It can be seen from Figure7 that in the centralized supply chain, with the increasing of  $\delta$ , the optimal pricing of direct channel is decrease, but the profit of manufacturer is increase, the reason is that the manufacturer improves the unit product wholesale price to retailer, so the manufacturer obtained the more product wholesale profit in retail channel,

and though the retailer improved the retail price of product, as the increasing of wholesale price, the retailer's profit have dropped. In the meanwhile, under the price addition contract, there exist a Pareto region such that the profit level of manufacturer and retailer is large than their respective profit in the decentralized one, therefore we can realize the coordination of supply chain by the price markup contract.

## 6. Concluding Remarks

The paper considered a supply chain system with a single product, and composed of one manufacturer and one retailer, the consumers are divided into retail store and brand loyalty two types, on this basis, we studied the influence of consumers channel preference on supply chain's pricing decision, and obtained the centralized and decentralized supply chain's equilibrium solution of Stackelberg game, and proved that the price markup contract can realized the coordination of supply chain, Numerical examples have proved the validity of conclusions.

In the further studies, we can consider introducing service in dual-channel supply chain, and further discuss the influence of service on pricing decision; it is insightful to study the pricing strategy of dual-channel supply chain with channel preference under the condition of asymmetric information, and consider the dual influence of asymmetric information and consumers' channel preference on supply chain's pricing decision.

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