Contract Risk Aversion of the Simulation Model of the Coordination between the Supply and Demand on Both Side

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***Abstract* — The article aims at researching the dual-channel supply chain composed of network direct sales channel and e-retail channel. On the basis of comparing manufacturer's and retailer's bargaining powers, the article analyzes supply chain members' price decision and logistics service level decision under three retail pricing models through game modelling. The research shows that the manufacturer's unified price model is the optimal model when the manufacturer has relatively weak bargaining power; the independent pricing model with the direct sales price as the bargaining basis is the optimal model when the manufacturer has relatively strong bargaining power. In the optimal model, the profits of the manufacturer and the supply chain are obviously dominant and the logistics service provided by e-retailers is correspondingly the best, but e-retailers' profits are not significantly influenced by the pricing model; and the optimal model is also the equilibrium strategy accepted by both parties.**

Keywords - dual-channel supply chain; bargaining power; stackelberg game; pricing model; service leve

I. INTRODUCTION

Along with the continuous improvement of retail market concentration and the sharp rising of large e-retailers, the relationship between the manufacturer and the retailers in the supply chain suffers from delicate change which is mainly presented in the bargaining power comparison [1]. The determination of the wholesale price in the supply chain has already been unable to be completely controlled by manufactures (take it or leave it offer) but is the game result based on the bargaining power of both parties. At present, the dual-channel supply chain issue has been analyzed in many literatures. Specifically, Kumar and Ruan, Kurata, et al. Cai, et al. have analyzed [2-7] the coordination issue of the dual-channel supply chain of the manufacturer respectively using network direct sales channel and retail channel through modeling, and it is in common in the research that the consumers are divided into two types, namely the customers loyal to manufacturer brand and the customers loyal to retailer, wherein the customers loyal to manufacturer brand only purchase the products of a certain manufacturer and the network direct sales channel can attract the customers loyal to brand. Moutaz, et al.have divided the consumers into two major groups: the customer group only consuming through traditional retail channel and the compound customer group not rejecting any channel. Hua, et al.have researched the lead time and the pricing decision issues of dual-channel supply chain. Chiang, et al.have analyzed the dual-channel model including online direct sales and physical store distributions on the basis of the utility theory and meanwhile have summarized that the direct sales can assist manufacturers to improve gross profits through reducing double marginalization [8]. Similar to Chiang, et al. , the consumers are assumed to have a relatively low utility assessment value upon the network channel products; for example, Fruchter and Tapiero , Cattani, et al.have analyzed three contextual models after the manufacturers with physical stores introduce network direct sales channel: (1) keep the wholesales price unchanged; (2) keep the retail price unchanged; (3) select the optimal wholesales price and retail price, and meanwhile have compared with the parameters before the network direct sales channel is introduced therein. Significantly, these literatures are all focused on consumer utility to obtain the demand function. In China, except the literatures of Chen Yun, et al , Guo Yajun and Zhao Liqiang [9-12], there are only a few literatures based on the consumer utility selection theory; and some literatures adopt the improved Hotelling model to analyze the conflict and the coordination of the dual-channel supply chain. For example, Pu Xujin, et al have researched the influence of network direct sales model on the retail channels of the strong retailers; Li Peiqin has researched the gaming competition relation among the manufacturer's network sales channel, the strong manufacturer and the weak retailers in the one vs. two supply chain under different e-commerce implementation degrees. The above literatures have researched the supply chain coordination issue from various aspects, but the research backgrounds thereof are all based on two heterogeneous channels, namely traditional channel and network direct sales channel, without the consideration of the wholesales price coordination issue. Significantly different from the existence of so many heterogeneities between the traditional channel and the network direct sales channel (physical channel VS e-channel), network direct sales channel and e-retailers are both e-channels, so they have fewer heterogeneities and their competition is mainly presented in service level and price, wherein the service level of e-channels mainly refers to logistics speed competition.

II. BASIC MODEL

A dual-channel supply chain composed of network direct sales channel and e-retail channel is considered in the article, and the supply chain structure is as shown in Fig. 1.

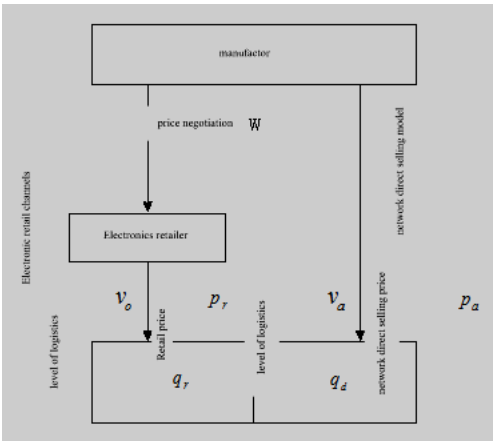

Figure 1. Structural diagram of dual-channel supply chain based on bargaining power

The service level (mainly referring to logistics speed) of the network direct sales channel is assumed as an exogenous constant, the e-retailer is assumed as a professional service provider, and meanwhile the logistics service level thereof is assumed to be usually not lower than that of the direct sales channel (e.g. Newegg has promoted 24h delivery logistics service). Therefore, we take the logistics speed v_a of the network direct sales channel as the standard and use v_0 to express the logistics speed of the e-retail channel to obtain $v = v_0 - v_a$. Therein, e-retailer's decision variable is the relative logistics service level v thereof. In order not to influence the analysis result, we take the logistics cost of the network direct sales channel (the logistics cost of this channel is assumed as 0) as the base price to obtain the logistics cost $\frac{rv^2}{2}$ of the e-retail channel. The reason for adopting quadratic cost function is as follows: during the logistics speed improvement, the logistics cost will have a sharp increasing process; in other words, the cost function is convex function. Therein, c stands for manufacturer's unit production cost.

The general form of the demand function is:

$$Q_a = a - P_a + c_1(P_o - P_a) - c_2(v_0 - v_a) \quad (1)$$

$$Q_o = b - P_o + c_1(P_a - P_o) + c_2(v_o - v_a) \quad (2)$$

Therein, subscript a stands for manufacturer, subscript o stands for e-retailer, a, b respectively refer to the market scales of network direct sales channel and e-retail channel, the market shares of direct sales channel and e-retail channel are respectively $\frac{a}{a+b}$ and $\frac{b}{a+b}$, $c_1 < 1$ is the price substitution coefficient and $c_2 < 1$ is the service level substitution coefficient.

III. STACKELBERG GAME ISSUE UNDER E-TRAILER'S UNIFIED PRICE

Demand functions (1) and (2) are simplified as:

$$Q_a = a - p - c_2 v \quad (3)$$

$$Q_o = b - p + c_2 v \quad (4)$$

Both parties bargain with each other to set the wholesale price, $w = \beta p$, and we adopt β to reflect the bargaining power comparison between manufacturer and e-retailer. When β is relatively large, it is indicated that manufacturer has stronger bargaining power during the bargaining process; when $1-\beta$ is relatively large, it is indicated that the retailer has stronger bargaining power during the bargaining process. During the bargaining process, it is necessary to meet the condition $w = \beta p \geq c$ in order to ensure that e-retailer and manufacturer can conclude a bargain.

The second stage: e-retailer determines retail price p and logistics level v.

$$\max_{p,v} \pi_o = (p - w)Q_o - \frac{rv^2}{2} \quad (5)$$

$$s.t. \quad \beta p \geq c$$

Hessian matrix of the objective function is:

$$H = \begin{pmatrix} 2\beta - 2 & (1-\beta)c_2 \\ (1-\beta)c_2 & -r \end{pmatrix}$$

For $\frac{\partial^2 \pi_o}{\partial p^2} < 0$ and $|H| = (1-\beta)(2r - c_2^2 + \beta c_2^2) > 0$, the objective function is a concave function related to p and v.

Then, KKT condition is used to form wholesale price $w = \beta p$ through bargaining and easily obtain theorem 1 which is not proven in the article due to space limit.

Theorem 1: if $\beta \geq \frac{c}{br}[2r - (1-\beta)c_2^2]$, then $p = \frac{br}{2r - (1-\beta)c_2^2}$, $v = \frac{(1-\beta)c_2 b}{2r - (1-\beta)c_2^2}$ and $w = \frac{\beta br}{2r - (1-\beta)c_2^2}$.

If $\beta < \frac{c}{br}(2r - (1-\beta)c_2^2)$, then $p = \frac{c}{\beta}$, $v = \frac{(1-\beta)cc_2}{\beta r}$ and $w = c$

According to theorem 1, $\frac{\partial p}{\partial (1-\beta)} > 0$ indicates that the retail price is directly proportional to retailer's bargaining power during the bargaining process; $\frac{\partial p}{\partial b} > 0$ indicates that the retail price is directly proportional to the market shares occupied by the retailer. Except that the service level is directly proportional to retailer's market share occupancy but is inversely proportional to the cost coefficient of the service, we can know $\frac{\partial v}{\partial (1-\beta)} > 0$ indicating that e-retailer's service level is directly proportional to the relative advantages thereof during the bargaining process for wholesale price and the strong retailer has higher service level.

IV. STACKELBERG GAME ISSUE UNDER MANUFACTURER'S UNIFIED PRICE

The demand functions for manufacturer channel and retailer channel are the same as formulae (3) and (4).

The second stage: e-retailer determines logistics level v.

$$\max_{v} \pi_o = (1-\beta) pQ_o - \frac{rv^2}{2} \tag{6}$$

For $\frac{\partial^2 \pi_o}{\partial v^2} < 0$, the target function is a concave function related to v and has maximum value.

Carry out the first derivation for π_o regarding v and then set it as 0 to solve the equation to obtain:

$$v = \frac{(1-\beta) pc_2}{r} \tag{7}$$

From formula (7), $\frac{\partial v}{\partial (1-\beta)} > 0$, $\frac{\partial v}{\partial p} > 0$, $\frac{\partial v}{\partial c_2} > 0$ and $\frac{\partial v}{\partial r} < 0$ indicate that retailer's service level is directly proportional to the retail price set by the manufacturer, and the influence effects of other factors are the same as the above conclusions.

The first stage: the manufacturer determines the wholesale price and the retail price of network direct sales.

$$\max_{w, p_a} \pi_a = (p-c)Q_a + (\beta p - c)Q_0 \tag{8}$$
$$s.t. \quad \beta p \geq c$$

Then, we can obtain theorem 2 through KKT condition.

Theorem 2:

if $\beta \geq \frac{2c}{(a+b\beta+2c)r}[r + (1-2\beta)c_2^2 + \beta r + \beta^2 c_2^2]$, then manufacturer's decision is $p = \frac{1}{2}\frac{(a+b\beta+2c)r}{r + (1-2\beta)c_2^2 + \beta r + \beta^2 c_2^2}$ and $w = \beta p = \frac{1}{2}\frac{(a+b\beta+2c)\beta r}{r + (1-2\beta)c_2^2 + \beta r + \beta^2 c_2^2}$, and retailer's decision is $v = \frac{1}{2}\frac{(1-\beta)(a+b\beta+2c)c^2}{r + (1-2\beta)c_2^2 + \beta r + \beta^2 c_2^2}$; if $\beta \leq \frac{2c}{(a+b\beta+2c)r}[r + (1-2\beta)c_2^2 + \beta r + \beta^2 c_2^2]$, then $p = \frac{c}{\beta}$, $w = c$ and $v = \frac{(1-\beta)cc_2}{\beta r}$.

V. STACKELBERG GAME ISSUE UNDER MANUFACTURER'S AND E-RETAILER'S INDEPENDENT PRICES

The demand functions are simplified as:

$$Q_a = a - p_a + c_1(p_o - p_a) - c_2 v \tag{9}$$

$$Q_o = b - p_o + c_1(p_a - p_o) + c_2 v \tag{10}$$

Under independent pricing model, there are two references for both parties to bargain: (1) take manufacturer's retail price as the basis; (2) take the retail price of the retail channel as the basis.

A. *Take Manufacturer'S Direct Sales Retail Price as Bargaining Basis*

Under independent pricing mode, the price has been set for manufacturer's direct sales channel, so both parties shall take manufacturer's retail price as the basis when determining the wholesale price w through bargaining.

The second stage: e-retailer determines logistics level v and p_o.

$$\max_{v, p_o} \pi_o = (p_o - \beta p_a)Q_o - \frac{rv^2}{2} \tag{11}$$

Hessian matrix of the objective function is:

$$H = \begin{pmatrix} -2c_1 - 2 & c_2 \\ c_2 & -r \end{pmatrix}$$

For $\frac{\partial^2 \pi_o}{\partial p_o^2} < 0$ and $|H| = 2r + 2c_1 r - c_2^2$, the objective function is a concave function related to p_o and v, and has a maximum value.

$$v = \frac{c_2(b - \beta p_a + c_1 p_a - c_1 \beta p_a)}{2r + 2c_1 - c_2^2} \tag{12}$$

$$p_o = \beta p_a + \frac{r(b - \beta p_a + c_1 p_a - c_1 \beta p_a)}{2r + 2c_1 r - c_2^2} \tag{13}$$

The second state: manufacturer determines the retail price of network direct sales.

$$\max_{p_a} \pi_a = (p_a - c)Q_a + (\beta p_a - c)Q_o \tag{14}$$
$$s.t. \quad \beta p \geq c$$

For $\frac{\partial^2 \pi_a}{\partial p_a^2} < 0$, the objective function is a concave function related to p_a and has a maximum value.

We will use KKT condition of the constrained optimization theory to solve the function. Due to the complexity of the formula, we will use numerical calculation example to calculate corresponding decision variables.

B. *Take Retailer'S Retail Price as the Bargaining Basis*

The second stage: e-retailer determines logistics level v and p_o.

$$\max_{v, p_o} \pi_o = (p_o - \beta p_o)Q_o - \frac{rv^2}{2} \tag{15}$$

Hessian matrix of the objective function is:

$$H = \begin{pmatrix} 2(c_1+1)(\beta-1) & -c_2(\beta-1) \\ -c_2(\beta-1) & -r \end{pmatrix}$$

For $\frac{\partial^2 \pi_o}{\partial p_o^2} < 0$ and $|H| = 2(c_1+1)(1-\beta)r - c_2^2(1-\beta)^2$, the objective function is a concave function related to p_o and v, and has a maximum value.

After solving the function, we can obtain:

$$v = \frac{c_2(1-\beta)(b+c_1 p_a)}{2r+2c_1 r+c_2^2\beta-c_2^2} \tag{16}$$

$$p_o = \frac{r\left(b+c_1 p_a\right)}{\left(\beta-1\right)c_2{}^2+2r+2c_1 r} \tag{17}$$

The first stage: manufacturer determines the retail price for network direct sales.

$$\max_{p_a} \pi_a = (p_a - c)Q_a + (\beta p_o - c)Q_o \tag{18}$$
$$s.t.\ \ \beta p \geq c$$

For $\frac{\partial^2 \pi_a}{\partial p_a{}^2} < 0$, the objective function is a concave function related to p_a and has a maximum value.

Similarly, we will use KKT condition of the constrained optimization theory to solve the function. Due to the complexity of the formula, we will use numerical calculation example to calculate the corresponding decision variable.

VI. NUMERICAL CALCULATION EXAMPLE

The system parameters are assumed as follows: the total market volume is 100, therein, $a = 50$ and $b = 50$. Other parameters are set as: $c_1 = 0.4$, $c_2 = 0.3$, $r = 0.5$ and $c = 10$; the price substitution coefficient and the service substitution coefficient are both less than free price sensitivity coefficient and such optimization conditions as $2r + 2c_1 r - c_2{}^2 > 0$ and $2r - c_2^2 + \beta c_2^2 > 0$ can be met.

We can know from Fig. 2: when manufacturer's bargaining power is fixed, as for the profits of the manufacturer and the supply chain, the manufacturer's unified pricing model is superior to the e-retailer's unified pricing model, but e-retailer does not have obvious preference to the two unified pricing models. Therefore, in the dual-channel supply chain with the wholesale price determined through bargaining, the unified pricing right shall be mastered by the manufacturer for equivalence strategy. We can know from the comparison of two bargaining bases under independent pricing model as shown Fig. 3: when manufacturer's bargaining power is fixed, as for the profits of the supply chain and the manufacture, the pricing model taking direct sales price as the bargaining basis is obviously superior to the pricing model taking the retail price set by e-retailer as the bargaining basis, but the two bargaining bases do not significantly influence e-retailer's preference. Under the same bargaining power of the manufacturer, the pricing model taking direct sales price as the bargaining basis is more capable of stimulating e-retailer to provide high-quality logistics service.

In order to find out the optimal pricing model for the manufacturer and the supply chain, we only need to compare the profits of the manufacturer and the supply chain respectively under manufacturer's unified pricing model and the independent pricing model taking the direct sales price as the bargaining basis, because we have known that the pricing model taking direct sales price as the bargaining basis is superior to the pricing model taking retail price as the bargaining basis and the manufacturer's unified pricing model is superior to the e-retailer's unified pricing model. We can know from Fig. 4: in the pricing model selection of dual-channel supply chain based on the bargaining power, from the aspect of considering the profits of the manufacturer and the supply chain, the manufacturer's unified pricing model is the optimal one among all pricing models when the manufacturer has relatively weak bargaining power.

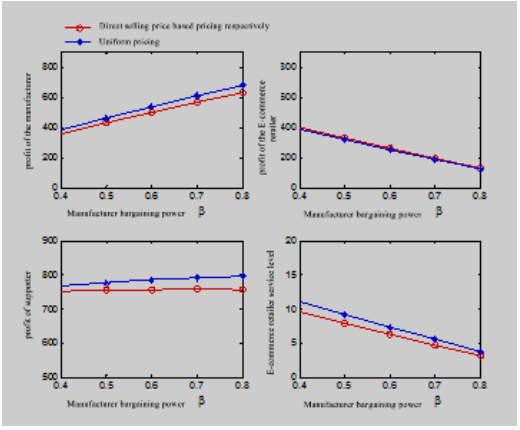

Figure 2. Contrastive analysis of e-retailer's unified pricing model and manufacturer's unified pricing model

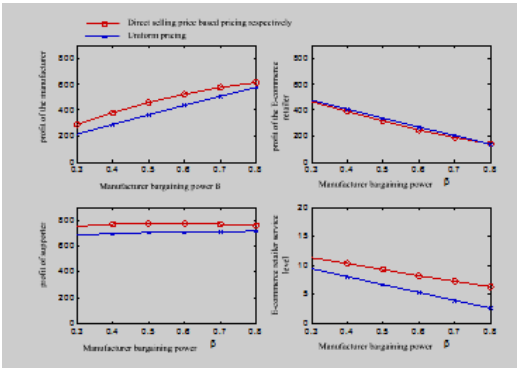

Figure 3. Bargaining basis comparison for independent pricing mode

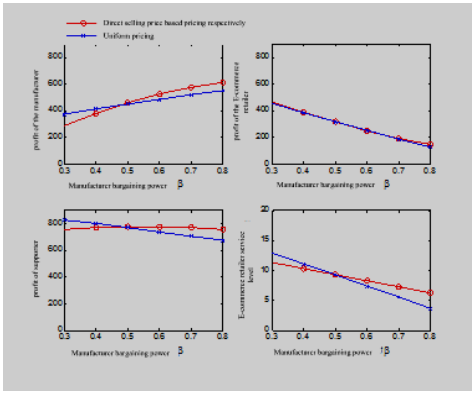

Figure 4. Optimal model selection for manufacturer and supply chain

VII. CONCLUSIONS CONFLICT OF INTEREST ACKNOWLEDGMENT

Along with the strengthened bargaining power of retailers in dual-channel supply chain, the wholesale price is usually determined by the bargaining power comparison between manufacturer and retailer, but the assumption that manufacturer can unilaterally control the wholesale price usually appears in past researches. Different from the past researches, the article adopts manufacturer's Stackelberg model as the analytical frame and gives a full consideration to the universality of wholesale price bargaining and the existence of multi-channel pricing models in actual environment as well as combines numerical calculation example to analyse the decision issue in the dual-channel supply chain containing service and price competitions. Under channel unequivalence strategy, the pricing model taking direct sales price as the bargaining basis is obviously superior to the pricing model taking the retail price set by e-retailer as the bargaining basis.

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