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ITJ

ISSN 1812-5638

INFORMATION TECHNOLOGY JOURNAL

ANSInet
Asian Network for Scientific Information
308 Lasani Town, Sargodha Road, Faisalabad - Pakistan

Information Technology Journal 13 (6): 1094-1101, 2014
ISSN 1812-5638 / DOI: 10.3923/itj.2014.1094.1101

Dual-channel Supply Chain Coordination with New Buy-back Contract Based on Fairness Preference Theory

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Abstract: In the general case of the non linear stochastic demand affected by the sales effort of the retailer, the fairness preference theory was applied to constructing Stackelberg game model between the manufacturer and the retailer. The manufacturer is self-interested, the retailer has a fairness preference. This study designs a new buy-back contract coordinating the dual-channel supply chain, the value of every parameter for the new buy-back contract which can coordinate the dual-channel supply chain, is achieved respectively. At last, the related digital simulation and example analysis were presented for the purpose of proofing the model theoretical analysis conclusions. Whether the retailer concerns fairness or not, the results show that coordination will always reach balance as long as the value of contract parameters meet certain conditions, the retailer's fairness preference does not affect the supply chain coordination conditions. However, the retailer's fairness preference will generates much negative utility to itself and the whole supply chain, the greater the level of fairness preference, the bigger the negative utility.

Key words: Supply chain coordination, dual-channel, fairness preference; new buy-back contract

INTRODUCTION

With the rapid development of the internet technology and the electronic commerce, online sales is becoming more and more easy, the professional development of the logistics industry also provide a strong security for the user, more and more consumers start to experience online shopping. According to the 29th Internet network development statistics report in China (CINIC, 2012), the number of people who use Internet in china had reached 513 million, over 160 million people shopping online and the scale of group purchase reached 64.65 million by the end of December, 2011. The number of network shopping user and the space of market growth will be enormous in the future. Therefore, more and more manufacturers choose to build their own online direct sales channels (simplified to direct channel) to widen the market share, increase market competitiveness. In foreign countries, some famous companies have their own direct channel such as HP, Nike, dell, IBM, Apple and so on; In china, some companies like Haier, Lenovo and other electric appliance manufacturers also have their own direct channel. However, with the addition of the manufacturers' direct channel, the traditional single retail channel mode has changed and the conflict between supply chain members has intensified. So, how to coordinate dual-channel supply chain effectively and improve supply chain performance becomes an important theoretical and practical problem (Tsay and Agrawal, 2004).

In fact, there are many literatures on the channel conflict and coordination of the dual-channel supply chain. Tsay and Agrawal (2004) designed the channel coordination mechanism in the context of electronic business and pointed out that the addition of the direct channel is not a bad thing to distributors in some extend. According to Dumrongsiri *et al.* (2008), the addition of the direct channel can improve the performance of the whole supply chain. Kurata *et al.* (2007) through the design of rise and down in price mechanism to achieve supply chain coordination under the brand competition circumstance. Chiang (2010) found that the dual-channel supply chain can achieve coordination by take measures that sharing inventory cost and revenue of direct channel. But in fact it is hard to carry out. Chen *et al.* (2012) showed that a two-part tariff or a profit-sharing agreement can coordinate the dual-channel supply chain under Stackelberg game model. Qu and Guo (2008) designed the coordinating revenue-sharing contract with the demand influenced by the retailer's effort level. Yu and Liu (2012) analyzed the dual-channel supply chain competition and coordination in the linear demand and combined promotion. The results show that the buy-back contract can bring benefit to both sides of the supply chain but can't achieve coordination. In addition, Wang and Zhang (2011) found that the effectiveness of dual-channel depends on consumer attributes and channel cost. Dan *et al.* (2012) designed a compensation strategy to coordinating the dual-channel supply chain from the aspect of channel cooperation.

The above research literatures about dual-channel supply chain conflict and coordination are all established in the hypothesis that the decision makers are completely

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selfish and did not take people's psychological factors into account. In real life, the theory of behavior science (Robbins, 2003) still emphasized that besides people's selfish preference, people also have a fairness preference and people not only concern their own material income but also focus on whether the distribution result of their material income is fair or not. The study results of Forsythe *et al.* (1994), Fahr and Irlenbusch (2000) and Fehr and Schmidt (1999) showed that people really have fairness preference psychology: When one's material income is less than other, the jealousy negative utility will produce because of the envy psychology; When one's material income is more than other, the guilty psychology can produce guilty negative utility. People are even willing to sacrifice part of their own profit to realize the fairness. For this, the research literatures in the field of supply chain coordination that consider the supply chain members' fairness preference psychology have increased gradually in recent years. Cui *et al.* (2007) pointed out that no matter only the retailer concerns fairness, or both sides pay attention to fairness, a coordinating wholesale price contract can be designed with the linear demand. Pavlov and Katok (2009) supposed that the supply chain member's fairness preference is private information. They found that due to the influence of the retailer's fairness preference, the equilibrium result of coordinating contract is that the manufacturer no longer completely occupy all the supply chain profit but tend to be divided into half and the contract efficiency is lower than 100%. Based on the hypothesis of the demand function is non-linear function, Caliskan-Demirag *et al.* (2010) expanded the results of Cui *et al.* (2007). They pointed out that comparing to linear demand function, the coordination conditions of index demand function are relatively loose only when the retailer concerns fairness.

In china, the applied research of fairness preference theory began with the behavioral decision game and incentive mechanism under the principal-agent theory. In the two-echelon supply chain field, we can look principals as manufacturers and look agents as retailers. Wei and Pu (2006) considered the effect of fairness preference on the trophy incentive and pointed out that the clients should take active measures to effectively identify agent's fairness preference and avoid the trophy competition between agents who have stronger fairness preference. Then, Wei *et al.* (2006) and Wei and Pu (2008) designed the optimal contract of multi-agent problem with fairness preference and examined the incentive efficiency of fairness preference. In the single-channel supply chain coordination field, Du *et al.* (2010) found that the retailer's fairness preference would not change the coordination state of supply chain. Then, Zhang and Shi (2010) on the basis of Du *et al.* (2010) considered the retailer's fairness preference and loss aversion simultaneously and obtained the similar conclusion. On the assumption that the market demand satisfies uniform distribution, Ma (2011) pointed out that the retailer's fairness preference can bring more bargaining power to itself and thus the retailer can obtain more supply chain profit. Liao and Wu (2010) made use of the research results by Wei *et al.* (2006) and discussed the optimal incentive mechanism of two-echelon agricultural products supply chain with the markdown money contract. In the dual-channel supply chain coordination field, the research results of Xing *et al.* (2011) showed that when the retailer's market share is lesser, the manufacturer will not pays attention to whether the retailer fells fair or not; When the retailer's market share is larger, the manufacturer will focus on channel fairness to avoid the punishment from the retailer by setting higher retail price. In addition, the channel fairness can improve the "double marginalization problem" effectively. But the model they established is very simple and did not consider the effect of the retailer's effort factor on market demand.

It is clear that the existing literatures either only focusing on the traditional single retail channel supply chain, or ignore the influence of the retailer's effort level. The literatures which make use of supply chain contract to discuss the dual-channel supply chain coordination problem with fairness preference members also are very few. Different with the above literatures, this study considers the general case of the non linear stochastic demand affected by the sales effort of the retailer and establishes Stackelberg game model between the manufacturer and the retailer with the fairness preference theory. Then, we design a new buy-back contract coordinating the dual-channel supply chain and obtain the coordination condition. At last, through the numerical example, we further analysis the effect of the retailer's fairness preference on supply chain member's utility.

HYPOTHESIS AND DENOTATION

Hypothesis: In order to the necessary mathematical simplification and follow the literature practices (Qu and Guo, 2008; Cachon, 2003; Taylor, 2002), we make the following hypothesis:

Hypothesis 1: The dual-channel supply chain model including only a manufacturer and a retailer, both of which are the risk neutral.

Hypothesis 2: The manufacturer not only through the retailer selling products to customers but also through the direct channel. The retailer faces a newsvendor problem and only has one stochastic sales season before the sales season and has only one chance to order from the manufacturer.

Hypothesis 3: The market demand is non-linear stochastic and influenced by the level of retailer's effort. The retailer's effort activities may not only be able to increase the sales quantity of retail channel but also be able to improve the direct channel's sales quantity. However, the manufacturer selling products through direct channel will reduce the retailer's sales quantity. Therefore, the competition and conflict between dual-channel is inevitable. This is a special problem that makes the dual-channel supply chain difficult to coordinate beside the double marginalization.

Hypothesis 4: The retailer concerns fairness, the manufacturer is fairness neutral. The retailer always takes the manufacturer's profit for reference and weighs up whether it obtains fair outcome. The assumption is reasonable: The retailer who closer to customer and in the selling terminal of the entire supply chain, is a natural person who has distinguishing fairness preference psychology in many cases; the manufacturer as a company organization whose fairness preference psychology is not obvious.

Hypothesis 5: In addition, we assume the retailer's goodwill penalty cost, the manufacturer's goodwill penalty cost, the direct channel's goodwill penalty cost and the product's net salvage value are zero.

The manufacturer and the retailer as mutual independent decision maker, it is a typical Stackelberg game relationship between them and the manufacturer is dominant in the supply chain. The manufacturer first decide the direct price, wholesale price and buy-back price, then, the retailer decide his effort level and retail price. The common goal is to pursue their maximum expected utility.

Denotation:

- e = The retailer's effort level, represents all the retailer's effort activities
- $G(e)$ = The retailer's effort cost of exerting effort level e. Without loss of generality, where $G(0) = 0$, $G(e)>0$, $G(e)>0$
- x = The total market demand which is non-linear stochastic. According to Taylor (2002), let $x = \Psi(e)\tau$, where $\Psi(e)$ is non-negative, differentiable and $\Psi(e)>0$, $\Psi(e)\leq 0$. τ is a random variable which independent to e and whose distribution function is $F(\tau)$, density function is $f(\tau)$
- $F_x(x|e)$ = The distribution function of total market demand. It is differentiable, strictly increasing. We note:

$$\bar{F}_X(x|e) = 1 - F_X(x|e)$$

- $f_x(x|e)$ = The density function of total market demand
- y = The demand of traditional retail channel, $y = \theta x$, where $\theta (0<\theta<1)$ presentation of the market share of retailer, θ is the function about e, do not break general, satisfies $\theta(e)>0$, $\theta(e)<0$
- z = The demand of direct channel, $z = (1-\theta)\,x$
- $F_T(y|e)$ = The demand distribution function of retail channel
- $f_T(y|e)$ = The demand density function of retail channel
- $F_E(z|e)$ = The demand distribution function of direct channel
- $f_E(z|e)$ = The demand density function of direct channel
- w_m = The wholesale price
- b_m = The buy-back price, namely, the price that the manufacturer pays the retailer for the remaining product, $b_m<w_m$
- P_T = The retail price
- P_E = The direct price
- c_m = The manufacturer's production cost per unit
- c_r = The retailer's marginal cost per unit
- c_E = The direct channel's marginal cost per unit
- q_T = The retailer's quantity, q_T is increasing in e
- q_E = The direct channel's quantity, q_E is decreasing in e
- α = The retailer's fairness preference level

The basic dual-channel supply chain model: Different to the traditional single retail channel, the manufacturer's profit includes the direct channel's profit under the dual-channel supply chain. The addition of direct channel will leads to competition and conflict between supply chain members. The retailer's effort not only affects the retail channel but also the direct channel. According to the above hypothesis, we can obtain that the distribution function of total market demand is:

$$F_X(x|e) = F\left(\frac{x}{\Psi(e)}\right)$$

the density function is:

$$f_X(x|e) = \frac{1}{\psi(e)} f(\frac{x}{\psi(e)})$$

The demand distribution function of retail channel is:

$$F_T(y|e) = F(\frac{x}{\theta(e)\cdot\psi(e)})$$

and hereby the density function is:

$$f_E(z|e) = \frac{1}{(1-\theta(e))\cdot\psi(e)} f(\frac{x}{(1-\theta(e))\cdot\psi(e)})$$

Let, $S_T(q_T, e)$ be the expected sales of retailer, $S_E(q_E, e)$ be the expected sales of direct channel and $Z(q_T)$ be the transfer payment function (the manufacturer gives to the retailer). According to the above conditions, through simple calculation, we can obtain: The retailer's expected sales is:

$$\begin{aligned} S_T(q_T, e) &= \int_0^{q_T} y f_T(y|e) d_y + \int_{q_T}^{\infty} q_T f_T(y|e) d_y \\ &= q_T - \int_0^{q_T} F_T(y|e) d_y \\ &= \frac{3}{2} q_T - \frac{1}{2\theta(e)\cdot\psi(e)} q_T^2 \end{aligned} \quad (1)$$

The expected sales of direct channel is:

$$\begin{aligned} S_E(q_E, e) &= \int_0^{q_E} z f_E(z|e) d_z + \int_{q_E}^{\infty} q_E f_E(z|e) d_z \\ &= q_E - \int_0^{q_E} F_E(z|e) d_z \\ &= \frac{3}{2} q_E - \frac{1}{2(1-\theta(e))\cdot\psi(e)} q_E^2 \end{aligned} \quad (2)$$

The above follows from integration by parts. Therefore, the retailer's expected profit function under dual-channel is:

$$\begin{aligned} \Pi_r(q_T, e) &= p_T S_T(q_T, e) - c_r q_T - G(e) - Z(q_T) \\ &= (\frac{3}{2} p_T - c_r) q_T - \frac{p_T}{2\theta(e)\cdot\psi(e)} q_T^2 - G(e) - Z(q_T) \end{aligned} \quad (3)$$

The manufacturer's expected profit function is:

$$\begin{aligned} \Pi_m(q_T, q_E, e) &= Z(q_T) - c_m q_T + p_E S_E(q_E, e) - c_E q_E \\ &= Z(q_T) - c_m q_T + (\frac{3}{2} p_E - c_E) q_E - \frac{p_E}{2(1-\theta(e))\cdot\psi(e)} q_E^2 \end{aligned} \quad (4)$$

and the dual-channel supply chain's profit function is:

$$\begin{aligned} \Pi_{sc}(q_T, q_E, e) &= p_T S_T(q_T, e) - (c_r + c_m) q_T \\ &\quad + p_E S_E(q_E, e) - c_E q_E - G(e) \\ &= (\frac{3}{2} p_T - c_r - c_m) q_T - \frac{p_T}{2\theta(e)\cdot\psi(e)} q_T^2 + (\frac{3}{2} p_E - c_E) q_E \\ &\quad - \frac{p_E}{2(1-\theta(e))\cdot\psi(e)} q_E^2 - G(e) \end{aligned} \quad (5)$$

Now consider the centralized decision. According to Eq. (5), for a given effort level, we can obtain $\partial^2\prod_{sc}(q_T, q_E, e)/\partial q_T^2 = -p_T/\theta(e).\Psi(e)<0$ and $\partial^2\prod_{sc}(q_T, q_E, e)/\partial q_T^2 = -p_E/(1-\theta(e)).\Psi(e)<0$. This mean that the dual-channel supply chain system exists only one optimal solution, i.e., the retailer's optimal order quantity q_T* satisfies:

$$q_T^* = \arg\frac{\partial\Pi_{sc}(q_T, q_E, e)}{\partial q_T} = 0$$

According to the first-order condition of Eq. (5), the specific retailer's optimal order quantity is:

$$q_T^* = \frac{\frac{3}{2} p_T - c_r - c_m}{p_T} \cdot \theta(e)\cdot\psi(e) \quad (6)$$

and the direct channel's optimal order quantity q_T* satisfies:

$$q_E^* = \arg\frac{\partial\Pi_{sc}(q_T, q_E, e)}{\partial q_E} = 0$$

i.e.:

$$q_E^* = \frac{\frac{3}{2} p_E - c_E}{p_E} \cdot (1-\theta(e))\cdot\psi(e) \quad (7)$$

In a similar way, the retailer's optimal effort level for a given q_T and q_E satisfy:

$$e^* = \arg\frac{\partial\Pi_{sc}(q_T, q_E, e)}{\partial e} = 0$$

According to the first-order condition of Eq. 5, the specific retailer's optimal effort level is:

$$e^* = \arg[p_T \frac{\partial S_T(q_T, e^*)}{\partial e} + p_E \frac{\partial S_E(q_E, e^*)}{\partial e} - G'(e^*)] = 0 \quad (8)$$

The new buy-back contract model based on retailer's fairness preference: In this study,, we adopt the fairness preference utility function (Du *et al*., 2010) has used. Let $\alpha<0$ be the fairness preference level. Algebraically, we have then:

$$\begin{aligned} u_r(\Pi) &= \Pi_r - \alpha(\Pi_m - \Pi_r) \\ &= (1+\alpha)\Pi_r - \Pi_m \end{aligned} \tag{9}$$

Divide Eq. 7 by $(1+\alpha)$, then the fairness preference utility function is given by:

$$\begin{aligned} U_r(\Pi) &= \frac{u_r(\Pi)}{1+\alpha} \\ &= \Pi_r - \frac{\alpha}{1+\alpha}\Pi_m \\ &= \Pi_r - \hat{\alpha}\Pi_m \end{aligned} \tag{10}$$

For $\alpha>0$, we know:

$$\hat{\alpha} = \frac{\alpha}{1+\alpha} \in (0,1)$$

is increasing in α. When $\alpha = 0$, then $\hat{\alpha} = 0$, i.e., the retailer is fairness neutral; When $\alpha \to \infty$, then $\hat{\alpha} \to 1$, i.e., the retailer concerns fairness extremely.

With a buy-back contract the manufacturer charges the retailer w_m ($w_m<p_T$) per unit purchased and pays the retailer b_m ($b_m<w_m$) per unit remaining at the end of the selling season. The transfer payment between manufacturer and retailer is:

$$\begin{aligned} Z(q_T, w_m, b_m) &= w_m q_T - b_m(q_T - S(q_T, e)) \\ &= b_m S(q_T, e) + (w_m - b_m)q_T \end{aligned} \tag{11}$$

However, according to Cachon (2003), the buy-back contract can not coordinate the supply chain with effort-dependent demand. The general processing method is that adding a contract parameter $\phi(0<\phi<1)$ on the buy-back contract model (Qu and Guo, 2008). Let ϕ be the fraction of effort cost the retailer bears. So $(1-\phi)$ is the fraction the manufacturer shares. In order to ensure the decision makers exist unique optimal decision, we assume $p_T>2b_m$. According to Eq. 3-11 The retailer's expected utility function is:

$$\begin{aligned} U_r(\Pi) &= (p_T - b_m)S_T(q_T, e) \\ &\quad - (c_r + w_m - b_m)q_T \\ &\quad - \phi G(e) - \hat{\alpha}[b_m S_T(q_T, e) \\ &\quad - (c_m - w_m + b_m)q_T + p_E S_E(q_E, e) \\ &\quad - c_E q_E - (1-\phi)G(e)] \\ &= [\frac{3}{2}p_T - (1+\hat{\alpha})(\frac{1}{2}b_m - w_m) - c_r + \hat{\alpha}c_m]q_T \\ &\quad - \frac{p_T - (1+\hat{\alpha})b_m}{2\theta(e)\cdot\psi(e)}q_T^2 - \hat{\alpha}(\frac{3}{2}p_E - c_E)q_E \\ &\quad + \frac{\hat{\alpha}p_E}{2(1-\theta(e))\cdot\psi(e)}q_E^2 + [\hat{\alpha} - \phi(1+\hat{\alpha})]G(e) \end{aligned} \tag{12}$$

According to Eq. 2 and 9, the manufacturer's expected utility function is:

$$\begin{aligned} \Pi_m(q_T, q_E, e, w_m, b_m) &= b_m S_T(q_T, e) \\ &\quad - (c_m - w_m + b_m)q_T + p_E S_E(q_E, e) \\ &\quad - c_E q_E - (1-\phi)G(e) \\ &= (\frac{1}{2}b_m - c_m + w_m)q_T - \frac{b_m}{2\theta(e)\cdot\psi(e)}q_T^2 \\ &\quad + (\frac{3}{2}p_E - c_E)q_E - \frac{p_E}{2(1-\theta(e))\cdot\psi(e)}q_E^2 \\ &\quad - (1-\phi)G(e) \end{aligned} \tag{13}$$

According to Eq. 3 and 9, the dual-channel supply chain's expected utility function is:

$$\begin{aligned} \Pi_{sc}(q_T, q_E, e, w_m, b_m) &= (p_T - b_m)S_T(q_T, e) \\ &\quad - (c_r + w_m - b_m)q_T - \phi G(e) \\ &\quad + (1-\hat{\alpha})[b_m S_T(q_T, e) - (c_m - w_m + b_m)q_T \\ &\quad + p_E S_E(q_E, e) - c_E q_E - (1-\phi)G(e)] \\ &= [\frac{3}{2}p_T - \frac{1}{2}\hat{\alpha}b_m - \hat{\alpha}w_m - c_r + \hat{\alpha}c_m - c_m]q_T \\ &\quad - \frac{p_T - \hat{\alpha}b_m}{2\theta(e)\cdot\psi(e)}q_T^2 + (1-\hat{\alpha})(\frac{3}{2}p_E - c_E)q_E \\ &\quad - \frac{p_E - \hat{\alpha}p_E}{2(1-\theta(e))\cdot\psi(e)}q_E^2 + [\hat{\alpha}(1-\phi) - 1]G(e) \end{aligned} \tag{14}$$

Now consider the decentralized decision. The retailer has unique optimal order quantity q_T^{**} because of $\partial^2 Ur(\prod)/\partial^2 q_T^2 = -(p_T(1+\hat{\alpha})b_m)/\theta(e)\Psi(e)<0$. By Eq. (12), the retailer's optimal order quantity for a given effort level satisfies:

$$q_T^{**} = \arg\frac{\partial U_r(\Pi)}{\partial q_T} = 0$$

i.e.:

$$q_T^{**} = \frac{\frac{3}{2}p_T - (1+\hat{\alpha})(\frac{1}{2}b_m - w_m) - c_r + \hat{\alpha}c_m}{p_T - (1+\hat{\alpha})b_m}\theta(e)\cdot\psi(e) \tag{15}$$

And the retailer's optimal effort level for a given q_T satisfies:

$$e^{**} = \arg\frac{\partial U_r(\Pi)}{\partial e} = 0$$

i.e.:

$$\begin{aligned} e^{**} &= \arg[(p_T - (1+\hat{\alpha})b_m)\frac{\partial S_T(q_T, e^{**})}{\partial e} \\ &\quad - \hat{\alpha}p_E\frac{\partial S_E(q_E, e^{**})}{\partial e} + (\hat{\alpha} - \phi(1+\hat{\alpha}))G'(e^{**})] \\ &= 0 \end{aligned} \tag{16}$$

According to the above Eq. 13, there is $\partial^2\prod_m(q_T, q_E, e, w_m, b_m)/\partial q_E^2 = -p_E/(1-\theta(e)).\Psi(e)<0$, i.e., the direct channel has unique optimal order quantity q^{**}_E. By Eq. 13, the direct channel's optimal order quantity for a given effort level satisfies:

$$q_E^{**} = \arg\frac{\partial \Pi_m(q_T, q_E, e, w_m, b_m)}{\partial q_E} = 0$$

i.e.:

$$q_E^{**} = \frac{\frac{3}{2}p_E - c_E}{p_E}(1-\theta(e))\cdot\psi(e) \tag{17}$$

The dual-channel supply chain coordination with fairness preference: The competition and conflict between the supply chain members will occur when the manufacturer adds a direct channel. To make the dual-channel supply chain achieves coordination, the coordination of the retailer's order quantity, effort level and the direct channel's order quantity must be realized. We can prove that as long as the value of every parameter for the new buy-back contract are appropriate, the dual-channel supply chain can achieve coordination. We can obtain the following proposition specifically and, respectively:

Proposition 1: In the dual-channel supply chain, even though there existing fairness preference psychology by retailer, the new buy-back contract also can coordinate the retailer's order quantity and the coordination condition has nothing to do with the retailer's fairness preference level:

$$w_m = b_m + c_m - \frac{c_r + c_m}{p_T} b_m \tag{18}$$

Proof of Proposition 1: If the retailer's order quantity achieved coordination, we have $q_T^{**} = q_T^{*}$, according to Eq. 15 and 6. We can obtain Eq. 18 through simple calculation.

It shows that no matter whether the retailer concerns fairness preference or not, as long as the contract parameters w_m and b_m satisfy Eq. 18, the retailer's order quantity always can be coordinated.

Proposition 2: In the dual-channel supply chain, even though there existing fairness preference psychology by retailer, the new buy-back contract also can coordinate the retailer's effort level and the coordination condition has nothing to do with the retailer's fairness preference level:

$$1-\phi = \frac{b_m \frac{\partial S_T(q_T, e)}{\partial e} + p_E \frac{\partial S_E(q_E, e)}{\partial e}}{G'(e)} \tag{19}$$

Proof of proposition 2: Similar to Proof of Proposition 1. If the retailer's effort level achieved coordination, we have $e^{**} = e^{*}$. According to Eq. 16 and 8, we can obtain Eq. 19 through simple calculation.

It shows that no matter whether the retailer concerns fairness preference or not, as long as the contract parameters ϕ and b_m satisfy Eq. 19, the retailer's effort level always can be coordinated.

The Eq. 7 and 17 show that the direct channel optimal order quantity is related to itself price, marginal cost and the retailer's effort level. With the retailer's effort level realized coordination, the coordination of the direct channel order quantity will be realized. So we can receive the following conclusion.

Conclusion: In the dual-channel supply chain, even though the retailer existing fairness preference psychology, the new buy-back contract also can coordinate the dual-channel supply chain as long as the value of every contract parameter satisfies certain condition.

NUMERICAL EXPERIMENT

In order to discuss the model and illustrate the conclusion more specifically, this section through numerical example analysis the optimal decision results of dual-channel supply chain members before and after channel coordination. We further analysis the effect of the retailer's fairness preference on supply chain members' utility.

Suppose a certain product has the following market characteristics: $\Psi(e) = 1000\ (1-e^{-1})$, $\theta(e) = \sqrt{e}/(\sqrt{e}+1)$, $x = 1000\ (1-e^{-1})$, where the random variable τ comply with uniform distribution at (0.5, 1.5), $G(e) = 50e^2$, $p_T = 120$, $c_r = 10$, $c_m = 30$, $p_E = 80$, $c_E = 8$, $w_m = 55$, $b_m = 25$, $\phi = 0.7$.

We put this parameters in the above model and make use of Matlab software, we can obtain the optimal decision results of decision-makers under centralized decision and decentralized decision and the value of every contract parameter when the supply chain achieve coordination (Table 1).

Table 1 shows that the retailer's order quantity, effort level and the direct channel order quantity under centralized decision higher than decentralized decision before coordination. The retailer's effort level is increasing but its order quantity is decreasing with the increase of fairness preference level under decentralized decision before coordination. Affected by the retail's effort level, the direct channel's order quantity is decreasing with the increase of retailer's effort level. When the new buy-back contract parameters satisfies $w_m \in (38, 70)$, $b_m \in (12, 60)$ and $\phi \in (0.62, 1)$, no matter the retailer's fairness preference level is $\hat{\alpha} = 0$ or $\hat{\alpha} > 0$, the

Table 1: Decision results of dual-channel supply chain

System index	The new buy-back contract model under decentralized decision						The basic model centralized decision
	Before coordination				After coordination		
α	0	0.8	3.0	0	0.8	3.0	/
$\hat{\alpha}$	0	0.44	0.75	0	0.44	0.75	/
e	10.93	12.19	13.45	11.39	11.39	11.39	11.39
q_T	753	730	709	821	821	821	821
q_E	295	286	278	292	292	292	292
q_m	55	55	55	(38, 70)	(38, 70)	(38, 70)	/
b_m	25	25	25	(12, 60)	(12, 60)	(12, 60)	/
ϕ	0.7	0.7	0.7	(0.62, 1)	(0.62, 1)	(0.62, 1)	/
π_r	34389	20017	10425	(4713, 45235)	(5791, 35425)	(-7250, 28665)	/
π_m	32826	31835	30783	(22094, 42616)	(22094, 42616)	(22094, 42616)	/
π_{sc}	67215	51852	41208	67329	(48407, 57519)	(35366, 50759)	67329

retailer's order quantity, effort level, as well as direct channel's order quantity are always able to achieve coordination in the dual-channel supply chain. Namely, no matter whether the retailer concerns fairness or not, as long as the buy-back contract parameters $\{w_m, b_m, \phi\}$ satisfy certain condition, the dual-channel supply chain always can be coordinated. That also verifies the conclusion of this paper. When we without consider the retailer's fairness preference, the dual-channel supply chain system utility under centralized decision not only higher than decentralized decision before coordination but also higher than decentralized decision system utility after coordination. In addition, the retailer and the whole supply chain utility are decreasing with the increase of the retailer's fairness preference level. It is clear that when the retailer's fairness preference is considered, although it has no influence on the retailer and the entire supply chain profit, it will cause a large disutility to the retailer and supply chain. That is to say that the greater the fairness preference level, the larger the disutility.

In order to more clearly and specifically examine the effect of the retailer's fairness preference on the utility of the supply chain decision makers, in the condition of Eq. 15 and 16, let $w_m = 50$, $b_m = 30$, $\phi = 0.86$, according to Eq. 9-11, we can obtain the supply chain members' utility, respectively with the different the retailer's fairness preference. Figure 1 reflects the effect of the retailer's fairness preference on the supply chain decision maker's utility.

Figure 1 clearly shows that with the increase of the retailer's fairness preference level, the retailer's utility appears decrease progressively. Because the manufacturer's utility remains unchanged, the entire supply chain's utility also presents decreasing. However, in the traditional single retail channel model, the retailer's fairness preference has caused the opposite effect: When the effect of the retailer's effort level on the market demand is not considered, the utility of the retailer and the supply chain will increase with the increase of the fairness preference level (Du *et al*., 2010). This is opposite to our conclusion from the Fig. 1. It indicates that with the

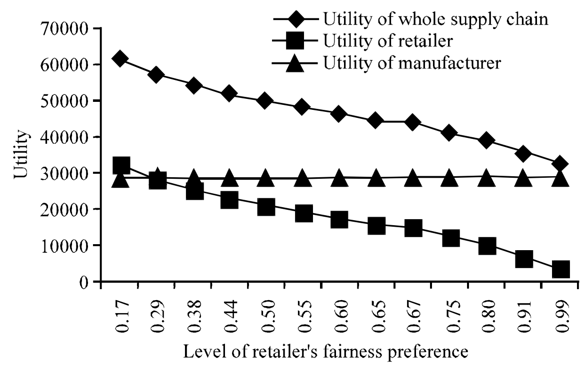

Fig. 1: The effect of the retailer's fairness preference on the utility of decision-makers

different channel background and different decision factor, the effect of retailer's fairness preference to the utility of itself and the supply chain is not the same.

CONCLUSION

In the general case of the non linear stochastic demand affected by the sales effort of the retailer, the fairness preference theory was applied to the dual-channel supply chain Stackelberg game model between the manufacturer and the retailer. The manufacturer is purely self-interested, the retailer has a fairness preference. This study designs a new buy-back contract coordinating the dual-channel supply chain. Because the traditional buy-back contract can't coordinate the supply chain with effort-dependent demand, this paper bring effort-cost-sharing parameter ϕ into the buy-back contract model. That is to say, the manufacturer shares some of the retailer's effort cost. The results show that even though the retailer exists fairness preference psychology, the new buy-back contract also can coordinate the dual-channel supply chain as long as every contract parameter has a appropriate value. Finally, through the numerical example, we analysis the optimal decision results of decision-makers under centralized decision and decentralized decision and verify the main conclusion of this paper. We further examine the effect of the retailer's fairness preference on the utility of supply chain members. We found that the utility of the retailer and the supply chain will decrease with the increase of the fairness preference level. Due to the manufacturer is fairness neutral, its utility is equal to its profit. However, this paper also has some limitations as follows: Firstly, we do not consider the manufacturer's fairness preference and effort factor. The manufacturer will also concerns fairness and exerts effort activities to improve the sales of direct channel in the real commercial activity. Secondly, channel members' other preference are not in concern, like risk preference. Therefore, we will engage to this work in the later.

ACKNOWLEDGMENT

This work was supported by National Nature Science Foundation of China under Grant No. 11070126.

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