An Information Sharing Model in Dual-channel Supply Chain in E-commerce Environment

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Abstract

This paper proposes a new information sharing model in hybrid dual-channel supply chain, which includes two retailers and one manufacturer with the electronic direct marketing. Based on whether the two retailers take part in the information sharing or not, three different information-sharing sub-models are introduced to resolve the optimal solution and analyze their stable Game Equilibrium. The optimal results and analysis show that to share uncertain demand information impacts on profits of supply chain in e-commerce environment, but it can not assure the increase in the total profit of supply chain unless under the specific conditions. The coordination between traditional channels and electronic channels is relevant to the basic demand and uncertain demand of retailers under certain conditions. The price discrimination strategy is an effective means to design information-sharing mechanism under the stable equilibrium conditions in dual-channel supply chain.

Key words: Supply Chain, Information Sharing, Dual-channel, Price Discrimination, E-commerce

1. Introduction

Information sharing may offset the bullwhip effect to improve performance, to lower costs and to reduce inventory in supply chain (Lee, et al. 1997a, Lee, et al. 1997b, Chen, 2000), but Z. Huang (2004, 2005) and L. Li (2002) etc. also point out that information sharing does not increase the profits of retailers. So appropriate incentive mechanisms must be designed to make retailers willing to share their private information with manufacturers (Huang,2004, Huang,2005, Li,2002). Cachon et al.(2001) study how to share forecast demand information through contract in a supply chain with one manufacturer that faces stochastic demand for a single product and one supplier. Their results show that optimal supply chain performance requires the manufacturer to share her initial forecast truthfully, but she has an incentive to inflate her forecast to induce the supplier to build more capacity. Raghunathan (2003) analyzes the value of demand information sharing in a one manufacturer–N retailer model in which demands of retailers may be correlated during a time period. Their analyses show that the demand correlation affects the magnitude and shape of the surplus function generated from information sharing. According to Stackelberg game model Zhang et al. (2004) study how to optimize supply prices and guide retailers to actively participate in information sharing from the perspective of the upper supplier in the supply chain. Li (2002) considers the strategy of price discrimination for retailers, but he believes that there is no incentive to use the strategy for supplier in pursuit of profit maximization because supplier must pay for additional information costs in order to encourage retailers to participate in information sharing. Liu et al. (2007) analyze a pricing incentive model in a distributed supply chain. From the perspective of the supplier, they further propose the use of price discrimination strategy to encourage retailers to participate in information sharing in a distributed supply chain with one single supplier and multiple retailers under constrained profit maximization. However, their study of the value and game analysis of information sharing is conducted only in the traditional supply chain.

With the rapid development of internet and the progress of information technology, e-commerce promotes changes of the structure in supply chain. Now many manufactures and suppliers establish direct sales channel through E-tailors while traditional sales channels remain unchanged. It is prevalent that direct sales channels and traditional sales channels coexist. The coordination mechanisms of such a hybrid dual channels in supply chain are new hot spots for studying. Tsay and Agrawal (2000) study the
cooperation mode of the dynamic channel structure in price and service competition. Further, Tsay and Agrawal (2004) analyze the structural properties of channels conflict with direct channel and coordination how to adjust manufacturer-reseller relationship in the E-commerce age. Yao and Liu (2005) study the wholesale prices in the structure of mixed retail channels and get the different optimal wholesale prices under Bertrand and Stackelberg competition. Chiang et al. (2003) study the strategic analysis and analyze the basic framework and dynamic coordination mechanism in dual channel supply chain. Chiang and Monahan (2005) study how to manage inventories in a two-echelon dual-channel supply chain with a traditional retail store and an Internet-enabled direct channel. Hisashi et al. (2007) analyze channel pricing coordination mechanism in multiple distribution channels between different brands with a direct channel and an indirect channel. Yao et al. (2009) study and compare the performance of three different inventory strategies for retail and e-tail stores to obtain the their respective optimal inventory levels and the respective expected profits in retail and e-tail stores.

The information sharing in the dual-channel supply chain has also become the new direction of research. Is the information sharing valuable in the dual-channel supply chain? Is the value of information sharing in the dual-channel supply chain the same in traditional sale channel? When is it valuable in the dual-channel supply chain? How is it valuable in the dual-channel supply chain? All these problems need to be addressed. Yao et al. (2005) analyze the impact of information sharing on a returns policy with the addition of a direct channel. Their study results show that information sharing is profitable for manufacturers and retailers. Mukhopadhyay et al. (2008) study the information sharing of value-adding retailer in a mixed channel hi-tech supply chain. According to their designed models retailers are willing to participate in information sharing. Yue and Liu (2004) assess the benefits of sharing demand forecast information in a manufacturer–retailer dual-channel supply chain with a traditional retail channel and a direct e-channel [19]. They find that the direct channel has a negative impact on the retailers’ performance, and, under some conditions, the manufacturer and the whole supply chain are better off.

In this study, there are different perspectives from their research. The study follows three aspects: (1)Dual channels exist in supply chain with electronic direct channel and retail channels for manufacturers, and the coordination is needed between electronic direct channel and retail channels; (2)It is uncertain whether retailers share private demand information which impacts certain performance of supply chain; (3) Price discrimination strategy is adopted, and retailers’ wholesale prices are different whether to participate in information sharing. In order to encourage retailers to participate in information sharing, the wholesale prices from the manufacturer to the retailers to participate in information sharing are lower than to other retailers not to participate in to share information. In this paper we consider information sharing model in a dual channel supply chain with one manufacturer who establishes an electronic direct channel and two retailers. In the research model price discrimination strategy is adopted to encourage retailers to participate in information sharing. According to the difference in two retailers whether to participate in information sharing, the model includes three cases: (1) retailers R1 and R2 are involved in information sharing; (2)retailer R1 participates in information sharing while retailer R2 does not participate in information sharing; (3)retailers R1 and R2 are not involved in information sharing.

In this paper, the optimal equilibrium solution and their profits of the foregoing three cases are respectively solved. Then the impacts of information sharing in dual-channel supply chain are analyzed through comparing equilibrium result to discover how to incent retailers to actively participate in information sharing and to realize the value of information sharing, to make electronic direct marketing and retail channels cooperate and win-win, and to improve the supply chain system performance.

2. Information-sharing Model in Dual-channel Supply chain

In this paper, the information sharing incentive model is built according to two retailers whether to share uncertain demand information in dual-channel supply chain with in one manufacturer M who establishes the electronic direct channel and two retailers R1 and R2, as shown in Figure 1 (Tsay and Agrawal 2000, Tsay and Agrawal 2004, Yao and Liu 2005, Chiang et al. 2003, Yao et al. 2009, Yao et al. 2005). In the model, customers can directly buy from the two retailers or directly purchase from the electronic direct marketing channels of the manufacturer. However, retailers deliver value-added of
services to customers while the retail price of retailers is higher than the price of the electronic direct marketing channel from manufacturers. Retailers are independent of each other and there isn’t competition between them, but customers freely transfer between the two retailers and direct channel because of price-sensitive, acquisition costs, access to opportunities, buying habits and other factors. In order to motivate retailers to participate in information sharing, manufacturers use price discrimination strategy to encourage retailers participating in information sharing in the model. In other words, the wholesale price for retailer to participate in information sharing is lower than for retailer not to participate in information sharing. The specific game structure of the model is three-stage sequence of decision-making. First of all, the manufacturer chooses whether to implement price discrimination strategies to incent retailers to share their private demand information, and the manufacturer decides the wholesale price of retailers and retail price of electronic direct channel in principle on its own profit-maximizing. Secondly, the retailers decide whether to share their private demand information or not. Finally, the retailers decide retail price in principle on their own profit-maximizing and issue order requirement, and then the manufacturer fulfills the retailer’s orders.

Assume the notations in the model as follows: \(\pi_1\) and \(\pi_2\) respectively are the profits of retailer R1 and R2, \(\pi_3\) is the profits of the manufacturer M. \(d_1\) and \(d_2\) are the demand of retailers R1 and R2 respectively. \(d_3\) is e-tail demand of manufacturer M. \(p_1\) and \(p_2\) are the retail price of retailers R1 and R2 respectively. \(p_3\) is e-tail prices of manufacturer. \(v_1\) and \(v_2\) are the value-added of retailers R1 and R2 respectively. \(c(v_1)\) is the cost of retailers R1 to provide the value-added \(v_1\), \(c(v_2)\) is the cost of retailers R2 to provide the value-added \(v_2\). \(w_1\) is the wholesale prices of retailer R1 to participate in information sharing. \(w_2\) is the wholesale prices retailer R2 not to participate in information sharing. \(t_i\) reflects the size of the signal for the market demand uncertainty, and its value is big for demand fluctuation-large while its value is also small for demand fluctuation-small. \(t_i\) is random variable of i.i.d. normal distribution with mean zero and variance \(\sigma_i^2\), namely \(t_i \sim N(0, \sigma_i^2)\). \(t_i\) may be negative, \(i = 1, 2, 3\). The optimal values of all parameters are marked by using the upper-right "**", which *= I, II and III, respectively, is the value of the optimal decision-making in foregoing three different cases: retailers R1 and R2 are involved in information sharing, the retailer R1 involved in information sharing while R2 does not participate in information sharing, and retailers R1 and R2 are not involved in information sharing.

Assumed that demand functions satisfy a linear relationship, retailers and manufacturer’s demand functions in dual-channel supply chain system with a value-added of services and free transfer between
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channels are as follows.

The demand function of retailer \( R_1 \):
\[
d_1 = D(p_1, p_1, v_1) = a_1 - b_1 p_1 + t_1 + \beta_1 (p_1 + v_1 - p_1)
\]

The demand function of retailer \( R_2 \):
\[
d_2 = D(p_2, p_2, v_2) = a_2 - b_2 p_2 + t_2 + \beta_2 (p_2 + v_2 - p_2)
\]

The demand function of manufacturer:
\[
d_3 = D(p_3, p_3, v_3, w_1, w_2) = a_3 - b_3 p_3 + t_3 + \beta_3 (p_3 + v_3 - p_3) + \theta (p_3 - v_3 - p_3)
\]

Where \( a_i \) (\( i = 1, 2, 3 \)) indicates the basic market demand of the different retail price; price fluctuation coefficient \( b \) indicated that the marginal price-sensitive demand coefficient; \( \beta_i \) (\( i = 1, 2 \)) expresses the marginal retail demand of retailer value-added of services; \( \theta \) is diffusion intensity to shift between the two channels with regards to the price and value-added, that is, the customers feel the difference of the price and value added between channels and they randomly shift between the two channels in proportion to \( \theta \) (Tsay and Agrawal, 2000, Tsay and Agrawal, 2004, Yao and Liu, 2005, Chiang et al. 2003, Chiang and Monahan, 2005, Yao et al., 2005, Mukhopadhyay et al., 2008); \( b \) and \( \theta \) are larger than 0. Retailers create the value-added \( v_i \) to compete with e-tail of manufacture, which satisfies the following cost function (Raghunathan, 2003, Tsay and Agrawal, 2000, Tsay and Agrawal, 2004):
\[
c(v_i) = \eta \frac{v_i^2}{2}, \; i = 1, 2. \text{ Where } \eta \text{ is the cost coefficient of value-added } v_i \text{ for retailers, } \eta > 0.
\]

To simplify calculation, the marginal costs of the various stages in supply chain are omitted. The retailers and the manufacturer’s profits functions are as follows, in which the manufacturer's profits include the profits from retailers and its own direct sales profits.

The profits function of Retailer \( R_1 \): \( \pi_1 = (p_1 - c(v_1) - w_1)d_1 \); The profits function of Retailer \( R_2 \): \( \pi_2 = (p_2 - c(v_2) - w_2)d_2 \); The profits function of Manufacturer: \( \pi_3 = w_1 d_1 + w_2 d_2 + p_3 d_3 \); The total profits function of the supply chain system: \( \pi_T = \pi_1 + \pi_2 + \pi_3 \).

3. Model Solution

The following idea is to solve the model: using backwards induction in game theory solves the three sub-models. Every specific uncertain private information \( t_i \) is different during the process of solving sub-model. If one does not know \( t_i \), its expectation 0 will replace \( t_i \) in the corresponding sub-model solution. Solving the model satisfies the following expression:

\[
\max_{p_1, v_1, w_1} \pi_1 = w_1 d_1 + w_2 d_1 + p_3 d_3, \quad \max_{p_1, v_1} \pi_1 = (p_1 - c(v_1) - w_1)d_1, \quad \max_{p_2, v_2} \pi_2 = (p_2 - c(v_2) - w_2)d_2.
\]

Because retailers \( R_1 \) and \( R_2 \) are independent of each other and both know private uncertain demand information, their decision-making solution processes are identical for retailers \( R_1 \) and \( R_2 \) whether to participate in information sharing or not and only the meaning of value of \( p_1, v_1, w_1, w_2 \) is different from one another for three different sub-models. The key difference of information-sharing in the foregoing three cases is the manufacturer's decision-making process and ultimate profit distribution mechanism. Then the following expression is based on different information sharing cases to obtain appropriate optimal solution for manufacture.

\[
\max_{p_1, v_1, w_2} \pi_3 = w_1 d_1 + w_2 d_2 + p_3 d_3
\]

3.1. The Decision-making of Retailer \( R_1 \)

Whenever the retailer \( R_1 \) whether participates in information sharing or does not, based on wholesale price \( w_1 \) from the manufacturer and his profit-maximizing principle, the retailer \( R_1 \) make a decision on
his retail price $p_1$ and value-added of services $v_1$ through solving $\max_{p_1,v_1} \pi$. Therefore, there is the following proposition.

**Proposition 1** For retailer $R_1$ whether to participate in information sharing or not, the manufacturer’s wholesale price $w_1$, its optimal equilibrium of decision-making on retail price $p_1$ and value-added of services $v_1$ are as follows respectively:

$$p_1 = \frac{3(\theta + \beta)^2}{4\eta(b+\theta)} + \frac{\alpha_1 + \theta p_1 + t_1 + (b+\theta)w_1}{2}$$

$$v_1 = \frac{\theta + \beta}{\eta(b+\theta)}$$

**Proof:** Due to the length of paper, the proofs of propositions are omitted.

### 3.2. The Decision-making of Retailer $R_2$

Similarly to retailer $R_1$, whenever retailer $R_2$ whether participates in information sharing or does not, retailer $R_2$ according to its own principles of profit-maximizing and wholesale price $w_2$ from manufacturer decides the retail price $p_2$ and the value-added of services $v_2$, which is to solve $\max_{p_2,v_2} \pi$.

**Proposition 2** For retailer $R_2$ whether to participate in information sharing, the manufacturer’s wholesale price $w_2$, its optimal equilibrium of decision-making on retail price $p_2$ and value-added of services $v_2$ are as follows respectively:

$$p_2 = \frac{3(\theta + \beta)^2}{4\eta(b+\theta)} + \frac{\alpha_2 + \theta p_2 + t_2 + (b+\theta)w_2}{2}$$

$$v_2 = \frac{\theta + \beta}{\eta(b+\theta)}$$

According to Proposition 1 and 2 the following Lemma can be drawn:

**Lemma 1** Retailer $R_1$ and $R_2$ are independent of each other and in accordance with the principles of their own profit-maximizing decide their value-added of services, but their value-added is equal in order to compete with each other.

**Lemma 2** Decision-making of value-added for retailers is not correlative with demand uncertain factor $t_i$ but only the cost coefficient of value-added $\eta$, price fluctuation coefficient $b$, value-added fluctuation coefficient $\beta_i$ and channel diffusion intensity $\theta$.

### 3.3. The Decision-making of Manufacturer

Based on whether the two retailers participate in information sharing, decision-making of the manufacturer is completely different in the foregoing three different situations because the manufacturer’s ability to access to the retailers’ private uncertain demand information is different. The following decision-making conditions are discussed and solved according to different cases.

#### 3.3.1. Retailers $R_1$ and $R_2$ are involved in information sharing

When retailers $R_1$ and $R_2$ are involved in information sharing, the manufacturer knows the uncertain market information $t_1$ of retailers $R_1$ and $t_2$ of retailers $R_2$, and he gives the same wholesale price to retailers $w_1 = w_2 = w_s$. The following propositions and conclusions can be obtained by solving the manufacturer's decision problem $\max_{p_1,v_1} \pi$.

**Proposition 3** The optimal equilibrium of decision-making on the retail price $p_1$ of manufacturer’s direct channel and wholesale price $w_s$ of retailers both to participate in information sharing are as follows:
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\[ w'_1 = \frac{(b + \theta)(\beta + \theta) + 4b^2(\beta + \theta)}{4\eta b + \theta}(b + 3\theta) + \frac{(b + 2\theta)(a_1 + a_2 + t_1 + t_2) + 2\Delta_3 + t_3)}{4(b + 3\theta)} \]

\[ p'_1 = \frac{(b - \beta)(\beta + \theta) + \theta(a_1 + a_2 + t_1 + t_2)}{b\alpha(b + 3\theta)} + \frac{(b + \theta)(a_1 + t_1) + \theta(a_1 + a_2 + t_1 + t_2)}{2b(b + 3\theta)} \]

Substitute the conclusions of Proposition 3 into the Propositions 1 and 2 to get the following conclusion.

**Proposition 4** When retailers R1 and R2 both participate in information sharing, the optimal equilibrium of decision-making on retailers’ retail price and value-added of services is as follows:

\[ p'_1 = \frac{(b + \theta)[8\beta\theta^2 + 7b^2(\beta + \theta) + b\theta(21\beta + 13\theta)] + (5b^2 + 15b\theta + 4\theta^2)(a_1 + t_1) + (b^2 + 3\beta\theta + 4\theta^2)(a_2 + t_2)}{8\eta b + \theta}(b + 3\theta) + \frac{(b + \theta)(a_1 + t_1) + \theta(a_1 + a_2 + t_1 + t_2)}{2b(b + 3\theta)} \]

\[ v'_1 = \frac{\theta + \beta}{\eta(b + \theta)} \]

3.3.2. Retailer R1 to participate in information sharing while R2 not to participate in information sharing

When retailer R1 participates in information sharing while retailer R2 does not, the manufacturer does not know uncertain market information \( t_2 \) of retailer R2 but does uncertain market information \( t_1 \) of retailer R1 and wholesale prices to retailers are different \( w_1 < w_2 \). The following propositions and conclusions can be got by solving the manufacturer's decision problem: \( \max_{p_1, t_1} \pi_3 \)

**Proposition 5** The optimal equilibrium of decision-making on the retail price \( p_1 \) of manufacturer's direct channel, wholesale price \( w_1 \) for retailer R1 to participate in information sharing and wholesale price \( w_2 \) for retailer R2 not to participate in information sharing are as follows:

\[ w'_1 = \frac{(b + \theta)[3\beta - \theta + 4\beta^2 + b^2(\beta + \theta)]}{4\eta b + \theta}(b + 3\theta) + \frac{(b^2 + 3\beta\theta + \theta a_1 + \theta a_2)}{2b(b + \theta)(b + 3\theta)} + \frac{\theta(a_1 + t_1)}{2b(b + 3\theta)} \]

\[ p'_1 = \frac{(b + \theta)(\beta - \theta) + \theta(a_1 + a_2 + t_1 + t_2)}{b\eta(b + \theta)(b + 3\theta)} + \frac{(b + \theta)(a_1 + t_1) + \theta(a_1 + a_2 + t_1 + t_2)}{2b(b + \theta)(b + 3\theta)} \]

Substitute the conclusions of Proposition 5 into the Propositions 1 and 2 to draw the following conclusion.

**Proposition 6** When retailer R1 participates in information sharing while retailer R2 does not, the optimal equilibrium of decision-making on retailers’ retail price and value-added of services are as follows:

\[ w'_2 = \frac{(b + \theta)[3\beta - \theta + 4\beta^2 + b^2(\beta + \theta)]}{4\eta b + \theta}(b + 3\theta) + \frac{(b^2 + 3\beta\theta + \theta a_1 + \theta a_2 + \theta(a_1 + a_2 + a_1 + a_2 + t_1 + t_2))}{2b(b + \theta)(b + 3\theta)} \]
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\[ p_1^w = \frac{(\beta + \theta)[8\beta \theta^2 + 7\theta^3(\beta + \theta) + b(2\beta + 13\theta)]}{8b\eta(b + \theta)(b + 3\theta)} + \frac{3\theta^2(a_t + t)}{8(h + \theta)(b + 3\theta)} \]
\[ v_1^w = \frac{\theta + \beta}{\eta(b + \theta)} \]

\[ p_2^w = \frac{(\beta + \theta)[8\beta \theta^2 + 7\theta^3(\beta + \theta) + b(2\beta + 13\theta)]}{8b\eta(b + \theta)(b + 3\theta)} + \frac{\theta^2(a_t + t)}{8(h + \theta)(b + 3\theta)} \]
\[ v_2^w = \frac{\theta + \beta}{\eta(b + \theta)} \]

3.3.3. Retailers R1 and R2 are not involved in information sharing

When retailers R1 and R2 are not involved in information sharing, the manufacturer does not knows the uncertain market information of retailers R1 and R2, and he gives the same wholesale price to retailers. The following propositions and conclusions can be reached by solving the manufacturer's decision problem.

**Proposition 7** The optimal equilibriums of decision-making on the retail price \( p_3 \) of manufacturer's direct channel and wholesale price \( w = uw \) for neither retailer to participate in information sharing are as follows:

\[ w_0^w = \frac{(\beta + \theta)[8\beta \theta^2 + 7\theta^3(\beta + \theta) + b(2\beta + 13\theta)]}{4b\eta(b + \theta)(b + 3\theta)} + \frac{(b + 2)(a_t + t)}{4(b + 3\theta)} \]
\[ p_1^w = \frac{(b - \beta)[9\beta \theta^2 + 8\beta \theta^3(\beta + \theta) + b(2\beta + 13\theta)]}{4b\eta(b + \theta)(b + 3\theta)} + \frac{(b + 2)(a_t + t)}{4(b + 3\theta)} \]
\[ v_1^w = \frac{\theta + \beta}{\eta(b + \theta)} \]

Substitute the conclusions of Proposition 7 into the Propositions 1 and 2 to get the following conclusion.

**Proposition 8** When neither retailer R1 and R2 participate in information sharing, the optimal equilibrium of decision-making on retailers' retail price and value-added of services are as follows:

\[ p_1^w = \frac{(\beta + \theta)[8\beta \theta^2 + 7\theta^3(\beta + \theta) + b(2\beta + 13\theta)]}{8b\eta(b + \theta)(b + 3\theta)} + \frac{\theta^2(a_1 + a_2 + a_t + t)}{2(b + 3\theta)} \]
\[ v_1^w = \frac{\theta + \beta}{\eta(b + \theta)} \]

3.4. The Benefits Distribution Mechanism

The foregoing three different situations are based on whether the two retailers participate in information sharing. Propositions 3-8 respectively substitute for the corresponding profit functions of manufacturer, retailers R1 and R2, to get the following profits distribution mechanism.

**Proposition 9** When retailers R1 and R2 both participate in information sharing, the profits of manufacturer, retailers R1 and R2 are as follows:

\[ \pi_1^w = \pi_1^t + \pi_2^t + \pi_3^t \]
\[ \pi_1^t = w_0^w d_1^t + w_0^w d_2^t + p_1^w d_3^t \]
\[ \pi_1^w = \frac{[(\theta + \beta)^2 - \eta(b + \theta)(a_t + 3a_2 + t_3 - 3t_3)]^2}{64\eta^2(b + \theta)^2} \]

**Proposition 10** When retailer R1 participates in information sharing while retailer R2 does not, the profits of manufacturer, retailers R1 and R2 are as follows:

\[ \pi_1^w = \pi_1^t + \pi_2^t + \pi_3^t \]
\[ \pi_1^t = w_0^w d_1^t + w_0^w d_2^t + p_1^w d_3^t \]
\[ \pi_1^w = \frac{[\beta + \theta]^2 - \eta(b + \theta)(a_t + 3a_2 + t_3 - 3t_3)]^2}{64\eta^2(b + \theta)^2} \]

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\[ \pi_i^{II} = \pi_i^{I} + \pi_i^{II} + \pi_i^{III} \]

\[ \pi_i^{II} = \frac{(2\gamma(b+\theta)(a_i + t_i) + (\theta + \bar{\theta})^2)}{64\eta^2(b + \theta)^4} \]

\[ \pi_i^{III} = \frac{1}{64\eta^2(b + \theta)^4} \left[ \{(b + \theta)^2 + \eta(b + \theta)(a_i + a_j + 2t_i + t_j) \} \{(b + \theta)^2 + 4\beta \theta \bar{\theta} + b^2(\beta + \bar{\theta})^2 \} + \eta(b + \theta)^2 \{(b + \theta)(a_i + a_j + 2t_i + t_j) + \theta(a_i + a_j) \} \right] \]

**Proposition 11** When neither of retailers R1 and R2 participates in information sharing, the profits of manufacturer, retailers R1 and R2 are as follows:

\[ \pi_i^{II} = \frac{(2\gamma(b+\theta)(a_i + t_i) + (\theta + \bar{\theta})^2)}{64\eta^2(b + \theta)^4} \]

\[ \pi_i^{III} = \frac{1}{64\eta^2(b + \theta)^4} \left[ \{(b + \theta)^2 + \eta(b + \theta)(a_i + a_j + 2t_i + t_j) \} \{(b + \theta)^2 + 4\beta \theta \bar{\theta} + b^2(\beta + \bar{\theta})^2 \} + \eta(b + \theta)^2 \{(b + \theta)(a_i + a_j + 2t_i + t_j) + \theta(a_i + a_j) \} \right] \]

4. Model analysis and discussion

Z. Huang and L. Li etc. point out that information sharing can offset the bullwhip effect to improve the overall performance of the supply chain (Lee and Padmanabhan, 1997a, Li, 2002), but they don’t analyze whether information sharing is equally effective in electronic commerce environment. In this section, the effectiveness of information sharing under e-commerce environment, dual-channel cooperation problems and the stability conditions of price discrimination policy are analyzed and discussed.

4.1. The Impact Analysis of Uncertain Demand Information Sharing on Profits of Supply Chain

4.1.1. The impact analysis of uncertain demand information sharing on the total profits of supply chain

Based on Propositions 9, 10, and 11 under different circumstances in supply chain, the profits difference between their different total profits can be calculated as follows:

\[ \pi_i^{II} - \pi_i^{III} = \frac{(t_i + t_j)[2t_i(b+3\theta)(\beta+\bar{\theta})^2 + \eta(b+\theta)[2t_i(b+3\theta)(a_i + a_j) + (\theta + 2\alpha + \theta^2)]]}{32\gamma(b+\theta)(b + 3\theta)} \]

\[ \pi_i^{III} - \pi_i^{III} = \frac{b\theta(b+3\theta)(a_i - a_j + t_i) - 2t_i(b+3\theta)(\beta+\bar{\theta})^2 + \eta(b+\theta)[b_i + \theta][b_i + \theta^2] + \eta(b+\theta)(b + 3\theta - 8\theta^2)]}{32\gamma(b+\theta)(b + 3\theta)} \]

If the information-sharing can increase the total profits of supply chain in electronic environment, there must be \( \pi_i^{II} - \pi_i^{III} > 0 \), that is there are \( \pi_i^{II} - \pi_i^{II} > 0 \), and \( \pi_i^{II} - \pi_i^{III} > 0 \) .
Simplify them as follows:

\[-(t_1 + t_2)\frac{2(b + 3\theta)(\beta + \theta)^2 + \eta(b + \theta)(2(b + 3\theta)(a_1 + a_2) + (b^2 + 3b\theta - 8\theta^2)(t_1 + t_2))}{\eta (b + \theta)} > 0\]

And

\[-b_2(b + \theta)(b + 3\theta)(a_1 - a_2)^2 - 2b_3(b + 3\theta)((\beta + \theta)^2 + \eta(b + \theta)(a_1 + a_2 + t_2))(b + \theta)(b + 3\theta) - 8\theta^2\]

Further simplification:

\[\frac{1}{2} \frac{(\beta + \theta)^2 + a_1 + a_2}{\eta (b + \theta) t_1 + t_2} < \frac{8\theta^2}{2\eta (b + 3\theta)} \text{ And } \frac{(a_1 - a_2 + t_2)^2 + 2t_1(\beta + \theta)^2 + 2t_1((b - \theta)(b + 4\theta) - \eta - 8\theta^2 t_2^2)}{b(b + 3\theta)} < 0\]

Therefore, to make information-sharing in electronic environment increase the total profits of supply chain must satisfy the above three conditions. Obviously beyond the above three conditions information sharing in electronic environment is not able to increase profits supply chain.

4.1.2. The impact analysis of uncertain demand information sharing on profits of retailers

According to Propositions 9, 10, and 11 obtained the optimal profits of retailers $R_1$ and $R_2$ under different circumstances, the difference of the profits between them in the same case, respectively, can be obtained, that is the values of $\pi_1^* - \pi_2^*$ ($*= I, II and III$) are as follows:

\[\pi_1^* - \pi_2^* = \frac{(a_1 - a_2 + t_2 - t_1)(\beta + \theta)^2 + \eta(b + \theta)(a_1 + a_2 + t_2)}{8\theta(b + \theta)}\]

\[\pi_1^* - \pi_2^* = \frac{(a_1 - a_2 + t_2 - 2t_2)(\beta + \theta)^2 + \eta(b + \theta)(a_1 + a_2 + t_2)}{8\theta(b + \theta)}\]

\[\pi_1^* - \pi_2^* = \frac{(a_1 - a_2 + t_2 - t_1)(\beta + \theta)^2 + \eta(b + \theta)(a_1 + a_2 + 2t_2)}{8\theta(b + \theta)}\]

If the retailer's fluctuating range of uncertain demand information is no more than half of the basic demand, the value of the above profits' difference $\pi_1^* - \pi_1^*$, $\pi_1^* - \pi_2^*$ and $\pi_1^* - \pi_2^*$ depends on the following simplified expression: $a_1 - a_2 + t_1 - t_2$, $a_1 - a_2 + t_2 - 2t_2$, and $a_1 - a_2 + t_2 - t_1$.

If $a_1 = a_2$ and $t_1 = t_2$, there is $\pi_1^* = \pi_1^*$ and $\pi_1^* = \pi_2^*$; the relationship between $\pi_1^*$ and $\pi_2^*$ depends on positive or negative value of $t_2$, when $t_2 > 0$, $\pi_1^* > \pi_2^*$ and when $t_2 < 0$, $\pi_1^* < \pi_2^*$.

4.2. The Cooperation between Traditional Channel and Electronic Channel

4.2.1. The impact of uncertain demand information sharing on prices of retailers

According to Propositions 4, 6 and 8 obtained the optimal retail price of retailers $R_1$ and $R_2$ under different circumstances, the values of $p_1^* - p_2^*$ ($*= I, II and III$) are obtained respectively as follows:

\[p_1^* - p_2^* = \frac{(a_1 - a_2 + t_2 - t_1)(\beta + \theta)^2 + \eta(b + \theta)(a_1 + a_2 + t_2)}{8\theta(b + \theta)}\]
Farther analysis shows that the relationship between the optimal retail price of retailers $R_1$ and $R_2$ depends only on $a_1$, $a_2$, $t_1$ and $t_2$. If $a_1 = a_2$ and $t_1 = t_2$, the optimal retail price of retailers $R_1$ and $R_2$ are equal in case I and III; while in case II, that is $p_i^u - p_i^l = \frac{t_i}{4(b + \theta)}$, their relationship is based on the actual value of $t_i$, when $t_i < 0$, $p_i^u - p_i^l < 0$, and $t_i > 0$, $p_i^u - p_i^l > 0$.

4.2.2. The cooperation of price between traditional channel and electronic channel

According to Propositions 3-8 obtained the optimal retail price of retailers $R_1$, $R_2$ and the manufacturer under different circumstances, respectively, it can be obtained that the retail price difference between retailer $R_1$ and manufacturer and between retailer $R_2$ and the manufacturer. Because the retail price of retailers is higher than the price of the electronic direct marketing channel from manufacturer, the difference of $p_1^i - p_1^l$, $p_2^i - p_2^l$, $p_i^u - p_i^l$ and $p_i^u - p_i^l$ is greater than 0. Simplify them into the following expressions:

$$
(p_i^l - p_i^l) = \frac{a_i - a_i + t_i - t_i}{2(b + \theta)}
$$

$$
(p_i^u - p_i^u) = \frac{3(a_i - a_i + t_i - t_i)}{4(b + \theta)}
$$

$$
(p_i^u - p_i^l) = \frac{a_i - a_i + t_i - t_i}{2(b + \theta)}
$$

That is if only the above six conditions are satisfied, the price between traditional channel and electronic direct channel can be cooperated, and retailers to provide customers with value-added of services and electronic channel of manufacturer can coexist to compete and coordinate. The above six conditions are complicated to make up the coordination mechanisms, which are not only correlated with the demand information uncertainty but also with many other coefficients between traditional channel and electronic channel.

4.3. The Stability Equilibrium Condition of Price Discrimination Strategy

According to Propositions 3, 5 and 7 manufacturer giving the retailer's wholesale price in different situations, it can obtain that the following wholesale price difference between the retailers to participate in information sharing in the case I and the retailers not to participate in information sharing in the case III; it can obtain also that the following wholesale price difference between the two retailers in the case II. It should be satisfied that the wholesale price for the retailers to participate in information sharing should be lower than for the retailers not to participate in information sharing in order to make equilibrium of price discrimination strategy stable.
\[ w_1^I - w_2^I = \frac{(b + 2\theta)(t_1 + t_2)}{4b(b + 3\theta)} \quad w_3^I - w_4^I = \frac{a_1 - a_2 + t_1}{2(b + \theta)} \]

That is \( w_1^I - w_2^I < 0 \) and \( w_3^I - w_4^I < 0 \). Further simplify them \( t_1 + t_2 < 0 \) and \( a_1 - a_2 + t_1 < 0 \). If price discrimination strategy is stable and effective which adopts a lower wholesale price for retailer to participate in information sharing, the following two conditions must be met in order to achieve a stable equilibrium: the sum of uncertain demand information of the two retailers is less than zero, and the sum of the basic demand uncertain demand and uncertain demand of retailer \( R_1 \) is less than the basic demand of retailer \( R_2 \).

5. Conclusion

This paper studies an information sharing model in hybrid dual-channel supply chain, which includes two retailers and one manufacturer with the electronic direct marketing. Based on whether the two retailers take part in the information sharing, there are three different information-sharing sub-models for the optimal solution and Game Equilibrium Analysis: retailers \( R_1 \) and \( R_2 \) are both involved in information sharing; retailer \( R_1 \) participates in information sharing while retailer \( R_2 \) does not participate in information sharing; neither retailer \( R_1 \) nor \( R_2 \) is involved in information sharing. The optimal results and analysis show that in e-commerce environment uncertain demand information sharing impacts on profits in supply chain, but it can not completely assure to increase the total profit in supply chain, which is only fit for the specific conditions, so the appropriate mechanisms of information sharing must be designed to maximize their total benefits in dual channel supply chain in e-commerce environment. The coordination between traditional channels and electronic channels is associated with the basic demand and uncertain demand of retailers, which is requested to fit for complex certain conditions. The stable equilibrium conditions of price discrimination strategy are correlated to the basic demand and demand uncertainty of retailers, so price discrimination strategy can be used as an effective means to design information sharing mechanism in dual-channel, supply chain in e-commerce environment.

Further research work is to design incentive mechanism of partial information sharing in specific situation which is retailer \( R_1 \) to participate in information sharing and \( R_2 \) retailer not to participate in information sharing in dual-channel supply chain in e-business environment, the pricing incentives model of partial information sharing in dual-channel supply chain with demand uncertainty, and the pricing incentive model of partial information sharing for multiple retailers in dual-channel supply chain.

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7. References

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