

# Price competition and equilibrium analysis in multiple hybrid channel supply chain

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**Abstract.** The amazing boom of Internet and logistics industry prompts more and more enterprises to sell commodity through multiple channels. Such market conditions make the participants of multiple hybrid channel supply chain compete each other in traditional and direct channel at the same time. This paper builds a two-echelon supply chain model with a single manufacturer and a single retailer who both can choose different channel or channel combination for their own sales, then, discusses the price competition and calculates the equilibrium price under different sales channel selection combinations. Our analysis shows that no matter the manufacturer and retailer choose same or different channel price to compete, the equilibrium price does not necessarily exist the equilibrium price in the multiple hybrid channel supply chain and wholesale price change is not always able to coordinate supply chain completely. We also present the sufficient and necessary conditions for the existence of equilibrium price and coordination wholesale price.

## 1. Introduction

With the rapid development of information technology, human way of life and work has been changed completely. Using Internet, consumers can search, compare and get plenty of information about the goods they want to buy conveniently and economically without restrictions of time, space, weather, etc. On the other hand, the improvement in the efficiency of merchandise delivery provided by the third-party logistics enterprises such as Federal Express and UPS makes merchants have the ability to deliver their products to customers quickly but not costly. The combination of traditional business model with information technology and logistics industry promotes the emergence and development of e-commerce and makes it no longer be a novelty.

The shortening of the length and the reduction of the intermediate links number of supply chain caused by online shopping reduce the price of products and benefit the customers. Meanwhile direct sale online makes enterprises more close to their customers and can obtain more accurate information for production operations management. Sale and purchasing through network became more and more popular and changed both enterprises' sales model and consumers' consumption patterns significantly. When electronic channel has become a critical selling and buying channel, manufacturers who sold only with the help of traditional retailers began to sell products to end customers directly via Internet. Such as IBM, Hewlett-Packard, Nike, Pioneer Electronics, Mattel, Estee Lauder and Cisco Systems, many prominent manufacturers had adopted primarily direct marketing techniques to sell their



products [1]-[3]. At the same time of manufacturers started selling online directly to complement their existing retail distribution networks, many traditional retailers also established network channel for obtaining more profits. For instance, in China, Suningyi in 2009 and Wal-Mart in 2010 began to sell products through network in succession.

Although online channel can provides wider coverage with lower operating costs than physical channels and provides easy access to vast numbers of potential customers, it still can't replace the role of physical channel in some ways like setting up the enterprise image and brand, offering after-sales service, etc. For consumers, they need get more detailed information about products through brick-and-mortar stores and take them as the assurance of corporate reputation and product quality. Both manufacturers and retailers will not give up using offline channel for selling, even though they build and operate their online channel. Some outstanding manufacturers even establish exclusive shops to sell their products for example Apple, Louis Vuitton, Haier and so on. If manufacturers or retailers use more than one channel for sales, the hybrid channel supply chain is created, and if manufacturers and retailers both use two or more channels to sell, the multiple hybrid channel supply chain is formed.

In multiple hybrid channel supply chain, manufacturers and retailers sell products with homogeneity through different channels. Consequently, customers have alternatives to choose the channel that is better suited for their needs to purchase [4]. Multiple hybrid channel distribution also enables enterprises to access different customer segments and create a potential for larger demand and market share, but it does not come without complications. While the manufacturers build their exclusive shops and direct channel, their retailer partners are not content with this practice and feel their profits have been deprived. In the market covered by overlapping independent channels, conflicts between manufacturers and retails, direct and traditional channel are almost inevitable. Among all of the conflicts, price competition is undoubtedly the most outstanding. Price is the only way for enterprises to gain profits, so the supply chain participants must come to grip with the problem of pricing strategy. The reasonable price can not only make firms profitable but also alleviate the contradictions in multiple hybrid channel supply chain.

In this paper, first the authors use the different structures of multiple hybrid channel supply chain to analyze pricing strategy of supply chain members and find equilibrium price, and then discuss the effect of wholesale price for supply chain coordination. The rest of this paper is organized as follows: Section 2 provides a review of related literature; Section 3 clarifies the types of multiple hybrid channel supply chain and finishes the preparatory work of modelling; In Section 4, we analyze the equilibrium price of different structures of multiple hybrid channel supply chain; The influence of same channel price competition strategy for the equilibrium price is studied in Section 5; In Section 6, the effect of wholesale price for supply chain coordination is discussed; Finally, conclusion remarks are given in Section 7.

## 2. Literature Review

With the boom of hybrid channel supply chain, conflicts between channels and members are escalating. In order to coordinate supply chain system effectively, more and more scholars and entrepreneurs have made a lot of effort for it. However, not all effective coordination mechanisms for traditional supply chain are applicable to hybrid channel supply chain. Boyaci observe that simple contracts, such as price-only, buy-back, rebate, revenue sharing, and VMI contracts, cannot coordinate the dual-channel supply chain because of the vertical and horizontal competition in both channels. But he demonstrated that a penalty contract or compensation-commission contract can coordinate the supply chain. Almost all of the literature in this field took it for granted that optimal pricing strategy [6]—is a major issue to attract customers and coordinate hybrid channel supply chain, so a considerable amount of research has been done on price competition and equilibrium of distribution channels.

Balasubramanian [10] build a competition model in a dual-channel environment from a strategic perspective and show that firms can use the level of market coverage as a mechanism to control competition then obtain the price equilibrium. The research of Chiang et al. [11] indicate that manufacturer and retailer who act independently will create a higher retail price, lower sales, and

lower profits without a direct channel and the vertically integrated direct channel allows manufacturer to constrain the pricing behavior of retailer. Chun et al. [12] analyze why there are price differences between a conventional retail channel and a direct online channel. Li et al. [13] show that in the markets where retail price consistency across channels is mandatory, an incumbent traditional brick-and-mortar retailer can deter the entry of a pure-play online retailer by strategically refraining from entering online. By contrast, in the markets where price consistency is not a constraint, the incumbent can deter the entry of a pure-play online retailer only if it enters online. In the latter case, the incumbent is willing to cannibalize its own brick-and-mortar business by charging a low online price. Fruchter et al. [14] find an optimal solution when the manufacturer adopts a non-discriminating pricing policy for both direct channel and retail channel. Ahn et al. [15] discuss about the pricing decisions of a dual-channel supply chain under the condition of traditional channel and direct channel operated in spatially separated markets. Cai et al. [16] show that the simple price discount contract can effectively improve both the supplier's and the retailer's performance based on evaluating the impact of a price discount contract and pricing scheme on the dual-channel supply chain competition. Yao et al. [17] build a dual channel supply chain model and discuss how the retailer to use prices and services to attract customers. Chen et al. [18] propose the pricing strategies of manufacturer in a dual-channel supply chain and show that the channel conflict can be resolved by applying two-part tariff or a price sharing agreement. Huang et al. [19] construct a deterministic demand model where the demand on a channel depends on prices, degree of substitution across channels and the overall market potential, then examine several prevalent pricing strategies which differ in the degree of autonomy for the Internet channel. The optimal retail service and prices in centralized and de-centralized dual-channel supply chain are determined in Dan et al. [20]. Xu et al. [21] investigate the impact of establishing a dual-channel supply chain coordinating contract when the supply chain agents are risk aversion under a mean-variance model, and propose the two-way revenue sharing contract to coordinate conflicts between channels. Chen et al. [22] examine how to make the proper decisions of the direct online sales channel together with a retail channel based on the same sales price and the different service levels of dual channel. Ren et al. [23] analyze the optimal decisions in both centralized and decentralized scenarios and design a contract to coordinate supply chain by proposing the dual-channel supply chain models considering consumer returns policies and the price and service competition between channels. Chen et al. [24] consider pricing policies in a dual-channel supply chain and show that improving brand loyalty is profitable for both the manufacturer and retailer and that an increased service value may alleviate the threat of the Internet channel for the retailer and increase the manufacturer's profits. Panda et al. [25] explore pricing and replenishment policies for a dual-channel supply chain with decreasing unit cost of product over its short life cycle.

Although there has been a lot of literature on the price competition of hybrid channel supply chain, the research about multiple hybrid channel supply chain is not common, especially on the supply chain where conflicts between manufacturers and retailers exist in online and offline channel simultaneously. Some of the few articles on this field include: Khouja et al. [26] analyze channel selection and price setting of a manufacturer who has several distribution options including direct channel, manufacturer-owned retail channel, and/or independent retail channel. Li et al. [27] analyze the price competition of the dual-channel supply chain composed of two oligopoly retailers (one sells through network and traditional store, the other sells only through the Internet). Kurata et al. [28] analyze channel pricing in a dual-channel system under competition between a national brand and a store brand and find that wholesale price change does not coordinate the supply chain. Hsiao et al. [29] investigate a channel selection problem between a direct channel and a retail channel for a manufacturer that incurs no production costs in a duopoly and show that the equilibrium where one manufacturer distributes products in both of the channels while the other manufacturer distributes only in the direct channel never arises. Li et al. [30] use the bifurcation theory of dynamical system to perform a numerical simulation on system with dual-channel retailer who makes delay decision considering different conditions and some complex phenomenon such as bifurcation and chaos. But these researches still can't analyze the price competition in multiple hybrid channel supply chain comprehensively. To

tackle this problem, this paper constructs two-echelon multiple hybrid channel supply chain models and investigates the price strategies of manufacturer and retailer based on linear demand function. We also examine the effect of wholesale price for supply chain coordination.

### 3. The model

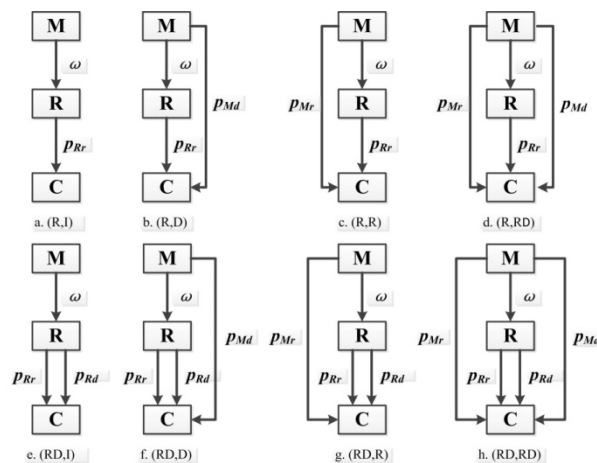
#### 3.1 Assumptions

Our paper establishes a two-echelon supply chain model with a single manufacturer and a single retailer. There is only one product being sold in the market, but both participants can choose different channel or channel combination for their own sales. For example, manufacturer can sell through direct channel and /or his own retail channel and/or independent retail channel, and at the same time retailer choose network and/or traditional store to sell commodity to customers. This model is based on the following assumptions:

- (1) The manufacturer (he) sells his product to independent retailer (she) and customers simultaneously. Firstly, he determines the wholesale price for retailer and the retail prices of his wholly owned channels, and then the retailer determines prices of her direct and/or traditional channel.
- (2) The manufacturer and retailer are both risk-neutral and take profit maximization as the goal to determine their channel prices.
- (3) To simplify the calculation, we suppose that manufacturer produces and sells and retailer sells a single product at an invariable marginal cost  $c=0$ .

#### 3.2 Model construction

Because of the different sales channel combination of manufacturer and retailer choosing, the multiple hybrid channel supply chain has different structures as shown in Figure 1. “M, R, C” represent manufacturer, retailer and customers respectively.



**Fig. 1** The structures of multiple hybrid channel supply chain

The manufacturer charges wholesale price  $\omega$  to retailer for his product and sells them to customers at  $p_{Mj}$ , in which M means the parameters of manufacturer and  $j=r, d$  represents the channel of his own retail and network. The retailer purchases product from manufacturer and then resell them at  $p_{Rj}$ , where R means the retailer's parameters. The retailer has two strategies to choose: “Strategy R” denotes that she resells product only through the traditional channel and “strategy RD” denotes that she distributes in both traditional and direct channel. The manufacturer's “Strategy I” means he sells his product only by independent retailer; “Strategy D” and “Strategy R” mean he uses both independent retailer and his own direct or retail channel for sales; “Strategy RD” means that he sells product through the above three channels simultaneously. In the eight kinds of two-echelon multiple

hybrid channel supply chain, the strategy combination (R, D) and (R, R), (RD, D) and (RD, R) are similar both in structure and analytical approach, so we choose strategy (R, I), (R, D), (R, RD), (RD, I), (RD, D), (RD, RD) as study objects to analyze (corresponding to fig. 1-a, b, d, e, f, h).

Considering the effect of different channel prices to channel demand, the demand functions of each channel are given by

$$q_{ij}^{(S_R, S_M)} = Q_{ij} - \alpha_{ij} p_{ij}^{(S_R, S_M)} - \beta_{ij} p_{ij}^{(S_R, S_M)} + \sum_{\substack{i=R, M \\ j=r, d}} \beta_{ij} p_{ij}^{(S_R, S_M)} \quad (1)$$

Where  $q_{ij}^{(S_R, S_M)}$  denotes channel demand (subscript  $i=R, M, j=r, d$ , and superscript  $(S_R, S_M)$  means channel strategy combination of manufacturer and retailer).  $Q_{ij}$  denotes the possible largest demand of channel.  $\alpha_{ij}$  is the coefficient of price elasticity of channel demand,  $\beta_{ij}$  is cross-price elasticity coefficient. It is quite reasonable that  $\alpha_{ij} > \beta_{ij} > 0$  i.e., the effect of price sensitivity of a channel is greater than cross-price effect. To facilitate the following discussion, let  $\alpha_{ij} = \alpha$ ,  $\beta_{ij} = \beta$ . We use  $\pi$  represent profits, so the enterprises' profit functions are

$$\pi_R^{(S_R, S_M)} = \sum_{j=r, d} q_{Rj}^{(S_R, S_M)} (p_{Rj}^{(S_R, S_M)} - \omega^{(S_R, S_M)}) \quad (2)$$

$$\pi_M^{(S_R, S_M)} = \sum_{j=r, d} q_{Mj}^{(S_R, S_M)} \omega^{(S_R, S_M)} + \sum_{j=r, d} q_{Mj}^{(S_R, S_M)} p_{Mj}^{(S_R, S_M)} \quad (3)$$

**Table 1.** Three Scheme comparing.

Numble	Scheme 1	Scheme 2	Scheme 3	Scheme 4	Scheme 5
1	456	456	123	123	123
2	789	213	644	644	644
3	213	654	649	649	649

#### 4. Price competition and Equilibrium analysis

In this section we discuss price competition according to the six kinds of multiple hybrid channel supply chain mentioned in 3.2 and get the equilibrium price combination.

##### 4.1 Strategy combination(R, I)

When manufacturer only through independent retailer and the retailer only through traditional store to sell product to customers, the channel demand is

$$q_{Rr}^{(R, I)} = a - \alpha p_{Rr}^{(R, I)} \quad (4)$$

In which  $a$  ( $a > 0$ ) denotes the possible largest demand of market. The retailer and manufacturer's profits are respectively

$$\pi_R^{(R, I)} = (p_{Rr}^{(R, I)} - \omega^{(R, I)}) q_{Rr}^{(R, I)} \quad (5)$$

$$\pi_M^{(R, I)} = \omega^{(R, I)} q_{Rr}^{(R, I)} \quad (6)$$

Because the manufacturer can determine the product wholesale price, he is the advantage of the game. According to Stackelberg game rule, we can deduce the optimal decision of supply chain

members using backward induction. Based on first-order conditions of the profit function  $\partial \pi_R^{(R,I)} / \partial p_{Rr}^{(R,I)} = 0$ , we can calculate the optimal reaction function of retailer

$$p_{Rr}^{(R,I)} = \frac{a + \alpha \omega^{(R,I)}}{2\alpha} \quad (7)$$

Substitute formula (7) into (6) and solve  $\partial \pi_M^{(R,I)} / \partial \omega^{(R,I)} = 0$ , can get

$$\omega^{(R,I)} = \frac{a}{2\alpha} \quad (8)$$

Then

$$p_{Rr}^{(R,I)} = \frac{3a}{4\alpha} \quad (9)$$

#### 4.2 Strategy combination (RD, I)

In this situation, manufacturer only sells through independent retailer but the retailer through both online and offline channel to sell product, the channel demands are

$$\begin{aligned} q_{Rr}^{(RD,I)} &= (1 - \rho)a - \alpha p_{Rr}^{(RD,I)} + \beta p_{Rd}^{(RD,I)} \\ q_{Rd}^{(RD,I)} &= \rho a - \alpha p_{Rd}^{(RD,I)} + \beta p_{Rr}^{(RD,I)} \end{aligned} \quad (10)$$

Where  $\rho$  ( $0 < \rho < 1$ ) is the market share of direct channel. The profit functions of supply chain members are

$$\begin{aligned} \pi_R^{(RD,I)} &= (p_{Rr}^{(RD,I)} - \omega^{(RD,I)})q_{Rr}^{(RD,I)} + (p_{Rd}^{(RD,I)} - \omega^{(RD,I)})q_{Rd}^{(RD,I)} \\ \pi_M^{(RD,I)} &= \omega^{(RD,I)}(q_{Rr}^{(RD,I)} + q_{Rd}^{(RD,I)}) \end{aligned} \quad (11)$$

The retailer's optimal reaction function is

$$\begin{aligned} p_{Rr}^{(RD,I)} &= \frac{\alpha(1 - \rho)a + \beta \rho a + (\alpha^2 - \beta^2)\omega^{(RD,I)}}{2(\alpha^2 - \beta^2)} \\ p_{Rd}^{(RD,I)} &= \frac{\alpha \rho a + \beta(1 - \rho)a + (\alpha^2 - \beta^2)\omega^{(RD,I)}}{2(\alpha^2 - \beta^2)} \end{aligned} \quad (12)$$

Solving this Stackelberg game, we can get the price equilibrium point

$$\begin{aligned} p_{Rr}^{(RD,I)} &= \frac{\alpha(1 - \rho) + \beta \rho + (\alpha + \beta)/4}{2(\alpha^2 - \beta^2)} a \\ p_{Rd}^{(RD,I)} &= \frac{\alpha \rho + \beta(1 - \rho) + (\alpha + \beta)/4}{2(\alpha^2 - \beta^2)} a \\ \omega^{(RD,I)} &= \frac{a}{4(\alpha - \beta)} \end{aligned} \quad (13)$$

#### 4.3 Strategy combination (R, D)

This strategy combination is the dual-channel supply chain that has been widely studied by many scholars. The channel demands and profit functions are respectively

$$\begin{aligned}
q_{Rr}^{(R,D)} &= (1 - \rho)a - \alpha p_{Rr}^{(R,D)} + \beta p_{Md}^{(R,D)} \\
q_{Md}^{(R,D)} &= \rho a - \alpha p_{Md}^{(R,D)} + \beta p_{Rr}^{(R,D)} \\
\pi_R^{(R,D)} &= (p_{Rr}^{(R,D)} - \omega^{(R,D)})q_{Rr}^{(R,D)} \\
\pi_M^{(R,D)} &= \omega^{(R,D)}q_{Rr}^{(R,D)} + p_{Md}^{(R,D)}q_{Md}^{(R,D)}
\end{aligned} \tag{14}$$

Because of the advantage of manufacturer, we first calculate the retailer's optimal reaction function

$$p_{Rr}^{(R,D)} = \frac{(1 - \rho)a + \beta p_{Md}^{(R,D)} + \alpha \omega^{(R,D)}}{2\alpha} \tag{15}$$

Based on first-order conditions of the profit function  $\partial \pi_M^{(R,D)} / \partial p_{Md}^{(R,D)} = 0$  and  $\partial \pi_M^{(R,D)} / \partial \omega^{(R,D)} = 0$ , we can get the price equilibrium point of strategy combination (R, D)

$$\begin{aligned}
p_{Rr}^{(R,D)} &= \frac{2\alpha\beta\rho + (3\alpha^2 - \beta^2)(1 - \rho)}{4\alpha(\alpha^2 - \beta^2)} a \\
p_{Md}^{(R,D)} &= \frac{\alpha\rho + \beta(1 - \rho)}{2(\alpha^2 - \beta^2)} a \\
\omega^{(R,D)} &= \frac{\beta\rho + \alpha(1 - \rho)}{2(\alpha^2 - \beta^2)} a
\end{aligned} \tag{16}$$

#### 4.4 Strategy combination (RD, D)

While the manufacturer uses his own network channel for sales, the retailer also constructs direct channel and uses it with her former traditional channel to sell simultaneously, we call this supply chain structure strategy combination (RD, D). Under this situation, each channel demand function and every enterprise's profit function are as following:

$$\begin{aligned}
q_{Rr}^{(RD,D)} &= (1 - \rho)a - \alpha p_{Rr}^{(RD,D)} + \beta p_{Rd}^{(RD,D)} + \beta p_{Md}^{(RD,D)} \\
q_{Rd}^{(RD,D)} &= (1 - \theta)\rho a - \alpha p_{Rd}^{(RD,D)} + \beta p_{Rr}^{(RD,D)} + \beta p_{Md}^{(RD,D)} \\
q_{Md}^{(RD,D)} &= \theta\rho a - \alpha p_{Md}^{(RD,D)} + \beta p_{Rr}^{(RD,D)} + \beta p_{Rd}^{(RD,D)} \\
\pi_R^{(RD,D)} &= (p_{Rr}^{(RD,D)} - \omega^{(RD,D)})q_{Rr}^{(RD,D)} + (p_{Rd}^{(RD,D)} - \omega^{(RD,D)})q_{Rd}^{(RD,D)} \\
\pi_M^{(RD,D)} &= \omega^{(RD,D)}(q_{Rr}^{(RD,D)} + q_{Rd}^{(RD,D)}) + p_{Md}^{(RD,D)}q_{Md}^{(RD,D)}
\end{aligned} \tag{17}$$

In which,  $\theta$  ( $0 < \theta < 1$ ) is the market share of manufacturer's direct channel. The retailer's optimal reaction functions are

$$\begin{aligned}
p_{Rr}^{(RD,D)} &= \frac{\alpha(1 - \rho)a + \beta(1 - \theta)\rho a + (\alpha + \beta)\beta p_{Md}^{(RD,D)} + (\alpha^2 - \beta^2)\omega^{(RD,D)}}{2(\alpha^2 - \beta^2)} \\
p_{Rd}^{(RD,D)} &= \frac{\alpha(1 - \theta)\rho a + \beta(1 - \rho)a + (\alpha + \beta)\beta p_{Md}^{(RD,D)} + (\alpha^2 - \beta^2)\omega^{(RD,D)}}{2(\alpha^2 - \beta^2)}
\end{aligned} \tag{18}$$

Substitute (18) into (17) and calculate the Hessian matrix of  $\pi_M^{(RD,D)}$  about  $\omega^{(RD,D)}$  and  $p_{Md}^{(RD,D)}$ :

$$H = \begin{bmatrix} -2(\alpha - \beta) & 2\beta \\ 2\beta & \frac{2\beta^2}{\alpha - \beta} - 2\alpha \end{bmatrix} \tag{19}$$



The necessary and sufficient conditions of (19) being negative definite is  $\alpha > 2\beta$ . When  $\alpha > 2\beta$ , we can get the price equilibrium point as follows. Otherwise, there will be no price equilibrium between manufacturer and retailer.

$$\begin{aligned}
 p_{Rr}^{(RD,D)} &= \frac{(5\alpha^2 - 9\alpha\beta + 2\beta^2)(1 - \rho) + (\alpha^2 + 3\alpha\beta - 6\beta^2)(1 - \theta)\rho + 4\beta(\alpha - \beta)\theta\rho}{8(\alpha^2 - \beta^2)(\alpha - 2\beta)} a \\
 p_{Rd}^{(RD,D)} &= \frac{(\alpha^2 + 3\alpha\beta - 6\beta^2)(1 - \rho) + (5\alpha^2 - 9\alpha\beta + 2\beta^2)(1 - \theta)\rho + 4\beta(\alpha - \beta)\theta\rho}{8(\alpha^2 - \beta^2)(\alpha - 2\beta)} a \\
 p_{Md}^{(RD,D)} &= \frac{\beta(1 - \rho) + \beta(1 - \theta)\rho + (\alpha - \beta)\theta\rho}{2(\alpha + \beta)(\alpha - 2\beta)} a \\
 \omega^{(RD,D)} &= \frac{\alpha(1 - \rho) + \alpha(1 - \theta)\rho + 2\beta\theta\rho}{4(\alpha + \beta)(\alpha - 2\beta)} a
 \end{aligned} \tag{20}$$

#### 4.5 Strategy combination (R, RD)

In strategy combination (R, RD), the manufacturer not only uses direct channel but also builds whole owned retail channel to compete with the independent retailer. But the independent retailer sell product to customers only through her traditional store. The channel demand functions and profit functions are respectively

$$\begin{aligned}
 q_{Rr}^{(R,RD)} &= (1 - \varepsilon)(1 - \rho)a - \alpha p_{Rr}^{(R,RD)} + \beta p_{Mr}^{(R,RD)} + \beta p_{Md}^{(R,RD)} \\
 q_{Mr}^{(R,RD)} &= \varepsilon(1 - \rho)a - \alpha p_{Mr}^{(R,RD)} + \beta p_{Rr}^{(R,RD)} + \beta p_{Md}^{(R,RD)} \\
 q_{Md}^{(R,RD)} &= \rho a - \alpha p_{Md}^{(R,RD)} + \beta p_{Rr}^{(R,RD)} + \beta p_{Mr}^{(R,RD)} \\
 \pi_R^{(R,RD)} &= (p_{Rr}^{(R,RD)} - \omega^{(R,RD)})q_{Rr}^{(R,RD)} \\
 \pi_M^{(R,RD)} &= \omega^{(R,RD)}q_{Rr}^{(R,RD)} + p_{Mr}^{(R,RD)}q_{Mr}^{(R,RD)} + p_{Md}^{(R,RD)}q_{Md}^{(R,RD)}
 \end{aligned} \tag{21}$$

Where  $\varepsilon$  ( $0 < \varepsilon < 1$ ) is the market share of manufacturer's offline channel. The retailer's optimal reaction function is

$$p_{Rr}^{(R,RD)} = \frac{(1 - \varepsilon)(1 - \rho)a + \beta p_{Mr}^{(R,RD)} + \beta p_{Md}^{(R,RD)} + \alpha \omega^{(R,RD)}}{2\alpha} \tag{22}$$

Calculate the Hessian matrix of  $\pi_M^{(R,RD)}$  about  $\omega^{(R,RD)}$ ,  $p_{Mr}^{(R,RD)}$  and  $p_{Md}^{(R,RD)}$ :

$$H = \begin{bmatrix} -\alpha & \beta & \beta \\ \beta & \frac{\beta^2 - 2\alpha^2}{\alpha} & \frac{2\alpha\beta + \beta^2}{\alpha} \\ \beta & \frac{2\alpha\beta + \beta^2}{\alpha} & \frac{\beta^2 - 2\alpha^2}{\alpha} \end{bmatrix} \tag{23}$$

The necessary and sufficient conditions of (23) being negative definite is  $\alpha < 2\beta$ . Based on the assumption  $\alpha > \beta$ , when  $\beta < \alpha < 2\beta$  we can get the optimal prices of manufacturer as follows:



$$\begin{aligned}
p_{Mr}^{(R, RD)} &= \frac{(\alpha - \beta)\varepsilon(1 - \rho) + \beta((1 - \varepsilon)(1 - \rho)a + \rho)}{2(\alpha + \beta)(\alpha - 2\beta)} a \\
p_{Md}^{(R, RD)} &= \frac{(\alpha - \beta)\rho + \beta((1 - \varepsilon)(1 - \rho) + \varepsilon(1 - \rho))}{2(\alpha + \beta)(\alpha - 2\beta)} a \\
\omega^{(R, RD)} &= \frac{(\alpha - \beta)(1 - \varepsilon)(1 - \rho) + \beta(\varepsilon(1 - \rho) + \rho)}{2(\alpha + \beta)(\alpha - 2\beta)} a
\end{aligned} \tag{24}$$

But when  $\beta < \alpha < 2\beta$ ,  $p_{Mr}^{(R, RD)}$ ,  $p_{Md}^{(R, RD)}$  and  $\omega^{(R, RD)}$  are all less than zero, so there is no reasonable price equilibrium in strategy combination (R, RD).

#### 4.6 Strategy combination (RD, RD)

Under this supply chain structure, both of the manufacture and retail sell their production through all kinds of sales channels. In other words, both of the manufacturer and retailer have online and offline channel for sales at the same time. The channel demand functions and profit functions are respectively

$$\begin{aligned}
q_{Rr}^{(RD, RD)} &= (1 - \varepsilon)(1 - \rho)a - \alpha p_{Rr}^{(RD, RD)} + \beta p_{Rd}^{(RD, RD)} + \beta p_{Mr}^{(RD, RD)} + \beta p_{Md}^{(RD, RD)} \\
q_{Rd}^{(RD, RD)} &= (1 - \theta)\rho a - \alpha p_{Rd}^{(RD, RD)} + \beta p_{Rr}^{(RD, RD)} + \beta p_{Mr}^{(RD, RD)} + \beta p_{Md}^{(RD, RD)} \\
q_{Mr}^{(RD, RD)} &= \varepsilon(1 - \rho)a - \alpha p_{Mr}^{(RD, RD)} + \beta p_{Rr}^{(RD, RD)} + \beta p_{Rd}^{(RD, RD)} + \beta p_{Md}^{(RD, RD)} \\
q_{Md}^{(RD, RD)} &= \theta\rho a - \alpha p_{Md}^{(RD, RD)} + \beta p_{Rr}^{(RD, RD)} + \beta p_{Rd}^{(RD, RD)} + \beta p_{Mr}^{(RD, RD)} \\
\pi_R^{(RD, RD)} &= (p_{Rr}^{(RD, RD)} - \omega^{(RD, RD)})q_{Rr}^{(RD, RD)} + (p_{Rd}^{(RD, RD)} - \omega^{(RD, RD)})q_{Rd}^{(RD, RD)} \\
\pi_M^{(RD, RD)} &= \omega^{(RD, RD)}(q_{Rr}^{(RD, RD)} + q_{Rd}^{(RD, RD)}) + p_{Mr}^{(RD, RD)}q_{Mr}^{(RD, RD)} + p_{Md}^{(RD, RD)}q_{Md}^{(RD, RD)}
\end{aligned} \tag{25}$$

Get the retailer's optimal reaction functions as follows:

$$\begin{aligned}
p_{Rr}^{(RD, RD)} &= \frac{\alpha(1 - \varepsilon)(1 - \rho)a + \beta(1 - \theta)\rho a + \beta(\alpha + \beta)(p_{Mr}^{(DR, DR)} + p_{Md}^{(DR, DR)}) + (\alpha^2 - \beta^2)\omega^{(RD, RD)}}{2(\alpha^2 - \beta^2)} \\
p_{Rd}^{(RD, RD)} &= \frac{\beta(1 - \varepsilon)(1 - \rho)a + \alpha(1 - \theta)\rho a + \beta(\alpha + \beta)(p_{Mr}^{(DR, DR)} + p_{Md}^{(DR, DR)}) + (\alpha^2 - \beta^2)\omega^{(RD, RD)}}{2(\alpha^2 - \beta^2)}
\end{aligned} \tag{26}$$

We can calculate the Hessian matrix of  $\pi_M^{(RD, RD)}$  about  $\omega^{(RD, RD)}$ ,  $p_{Mr}^{(RD, RD)}$  and  $p_{Md}^{(RD, RD)}$ :

$$H = \begin{bmatrix} -2\frac{\alpha^2 - \alpha\beta - \beta^2}{\alpha - \beta} & 2\frac{\alpha\beta}{\alpha - \beta} & 2\beta \\ 2\frac{\alpha\beta}{\alpha - \beta} & -2\frac{\alpha^2 - \alpha\beta - \beta^2}{\alpha - \beta} & 2\beta \\ 2\beta & 2\beta & -2(\alpha - \beta) \end{bmatrix} \tag{27}$$

If and only if  $(1 + \sqrt{5})\beta/2 < \alpha < 3\beta$ ,  $\pi_M^{(RD, RD)}$  is concave. With this constraint we can get the optimal prices of manufacturer as follows:

$$\begin{aligned}
p_{Mr}^{(RD, RD)} &= \frac{\beta(1-\varepsilon)(1-\rho) + (1-\theta)\rho + \theta\rho + (\alpha-2\beta)\varepsilon(1-\rho)}{2(\alpha+\beta)(\alpha-3\beta)} a \\
p_{Md}^{(RD, RD)} &= \frac{\beta(1-\varepsilon)(1-\rho) + (1-\theta)\rho + \varepsilon(1-\rho) + (\alpha-2\beta)\theta\rho}{2(\alpha+\beta)(\alpha-3\beta)} a \\
\omega^{(RD, RD)} &= \frac{(\alpha-\beta)((1-\varepsilon)(1-\rho) + (1-\theta)\rho) + 2\beta(\varepsilon(1-\rho) + \theta\rho)}{4(\alpha+\beta)(\alpha-3\beta)} a
\end{aligned} \quad (28)$$

But when  $(1 + \sqrt{5})\beta / 2 < \alpha < 3\beta$ ,  $p_{Mr}^{(RD, RD)}$ ,  $p_{Md}^{(RD, RD)}$  and  $\omega^{(RD, RD)}$  are all less than zero, so there is no reasonable price equilibrium in strategy combination (RD, RD).

In the last, the results of the equilibrium price based on six kinds of multiple hybrid channel supply chain are summarized in Table 2.

**Table.2** Equilibrium price of multiple hybrid channel supply chain

Strategy	Manufacturer			
	I	D	RD	
R	$\omega^{(R,I)} = \frac{a}{2\alpha}$	$p_{br}^{(R,D)} = \frac{2\alpha\beta\rho + (3\alpha^2 - \beta^2)(1-\rho)}{4\alpha(\alpha^2 - \beta^2)}a$	No reasonable price equilibrium	
	$p_{br}^{(R,I)} = \frac{3a}{4\alpha}$	$p_{bd}^{(R,D)} = \frac{\alpha\rho + \beta(1-\rho)}{2(\alpha^2 - \beta^2)}a$ $\omega^{(R,D)} = \frac{\beta\rho + \alpha(1-\rho)}{2(\alpha^2 - \beta^2)}a$		
Retailer		When $\alpha>2\beta$		
	$p_{br}^{(RD,I)} = \frac{\alpha(1-\rho) + \beta\rho + (\alpha + \beta)/4}{2(\alpha^2 - \beta^2)}a$	$p_{br}^{(RD,D)} = \frac{(5\alpha^2 - 9\alpha\beta + 2\beta^2)(1-\rho) + (\alpha^2 + 3\alpha\beta - 6\beta^2)(1-\theta)\rho + 4\beta(\alpha - \beta)\theta\rho}{8(\alpha^2 - \beta^2)(\alpha - 2\beta)}a$ $p_{bd}^{(RD,D)} = \frac{(\alpha^2 + 3\alpha\beta - 6\beta^2)(1-\rho) + (5\alpha^2 - 9\alpha\beta + 2\beta^2)(1-\theta)\rho + 4\beta(\alpha - \beta)\theta\rho}{8(\alpha^2 - \beta^2)(\alpha - 2\beta)}a$	No reasonable price equilibrium	
RD	$p_{br}^{(RD,I)} = \frac{\alpha\rho + \beta(1-\rho) + (\alpha + \beta)/4}{2(\alpha^2 - \beta^2)}a$ $\omega^{(RD,I)} = \frac{a}{4(\alpha - \beta)}$	$p_{br}^{(RD,D)} = \frac{\beta(1-\rho) + \beta(1-\theta)\rho + (\alpha - \beta)\theta\rho}{2(\alpha + \beta)(\alpha - 2\beta)}a$ $\omega^{(RD,D)} = \frac{\alpha(1-\rho) + \alpha(1-\theta)\rho + 2\beta\theta\rho}{4(\alpha + \beta)(\alpha - 2\beta)}a$		
		Otherwise, no price equilibrium.		

## 5. Price competition and Equilibrium analysis

In Section 4, the price competition and equilibrium between the manufacturer and retailer in different structures of multiple hybrid channel supply chain are studied. Sometimes, the same price strategy may be taken by supply chain members for the purpose of competition. The same price means that if the manufacturer and retailer use the same channel to sell simultaneously, they will charge the same channel price of commodity to customers. To distinguish conveniently, we use lowercase superscript to identify parameters of same price strategy. From Fig.1, the same price strategy can be taken in the strategy combination (r, r), (r, rd), (rd, d), (rd, r) and (rd, rd), but (rd, d) and (rd, r) are similar both in structure and analytical approach, so we choose strategy (r, r), (r, rd), (rd, d) and (rd, rd) as study objects. We suppose the demand functions under same price strategy are

$$q_{ij}^{(s_R, s_M)} = Q_{ij} - \alpha p_j^{(s_R, s_M)} + \gamma p_{Cuj}^{(s_R, s_M)} \quad (29)$$

In which,  $\gamma$  is the cross-price elasticity coefficient and  $\alpha > \gamma > 0$ , “Cuj” means the complementation of set j. By solving the Stackelberg game under different supply chain structures, we can get the equilibrium price of same price strategy shown in Table. 3.

**Table.3** The equilibrium price of same price strategy

strategy	Equilibrium Price
(r, r)	$p_r^{(r,r)} = \frac{(3-2\varepsilon)a}{6\alpha} \quad \omega^{(r,r)} = \frac{\varepsilon a}{3\alpha}$ <p>When <math>\alpha &gt; \gamma\sqrt{12/13}</math></p>
(r, rd)	$p_r^{(r,rd)} = \frac{(6\alpha^2 - 4\gamma^2)(1-\varepsilon)(1-\rho) + 2(\alpha^2 + \gamma^2)\varepsilon(1-\rho) + 5\alpha\gamma p_a}{\alpha(12\alpha^2 - 13\gamma^2)} \quad p_d^{(r,rd)} = \frac{\gamma(3(1-\varepsilon)(1-\rho) + 5\varepsilon(1-\rho)) + 6\alpha p_a}{12\alpha^2 - 13\gamma^2}$ $\omega^{(r,rd)} = \frac{2\gamma^2(1-\varepsilon)(1-\rho) + (4\alpha^2 - \gamma^2)\varepsilon(1-\rho) + 4\alpha\gamma p_a}{\alpha(12\alpha^2 - 13\gamma^2)}$
(rd, d)	<p>Otherwise, no price equilibrium.</p> $p_r^{(rd,d)} = \frac{(12\alpha + \gamma)(1-\rho) + 11\gamma(1-\theta)\rho + 2(\alpha + \gamma)\theta p_a}{20(\alpha^2 - \gamma^2)}$ $p_d^{(rd,d)} = \frac{(2\alpha + 11\gamma)(1-\rho) + (10\alpha + \gamma)(1-\theta)\rho + 2(\alpha + \gamma)\theta p_a}{20(\alpha^2 - \gamma^2)}$ $\omega^{(rd,d)} = \frac{(2\alpha + \gamma)((1-\rho) + \theta\rho) + \gamma p_a}{10(\alpha^2 - \gamma^2)}$
(rd, rd)	$p_r^{(rd,rd)} = \frac{6(\alpha(1-\varepsilon)(1-\rho) + \gamma(1-\theta)\rho) + (\alpha + \gamma)(\varepsilon(1-\rho) + \theta\rho)}{12(\alpha^2 - \gamma^2)}$ $p_d^{(rd,rd)} = \frac{6(\alpha(1-\theta)\rho + \gamma(1-\varepsilon)(1-\rho)) + (\alpha + \gamma)(\varepsilon(1-\rho) + \theta\rho)}{12(\alpha^2 - \gamma^2)}$ $\omega^{(rd,rd)} = \frac{\varepsilon(1-\rho) + \theta\rho}{6(\alpha - \gamma)}$

## 6. Effect of wholesale price for supply chain coordination

The overall return of integrated supply chain is optimal in all types, to coordinate multiple hybrid channel supply chain we should calculate the optimal prices of integrated supply chain firstly. Using  $\Pi$ ,  $P$  and  $\Omega$  denote the profits, channel price and wholesale price of centralized decision, the profit function of integrated supply chain can be expressed

$$\Pi^{(S_R, S_Y)} = \sum_{\substack{i=R, M \\ j=r, d}} q_{ij}^{(S_R, S_Y)} P_{ij}^{(S_R, S_Y)} \quad (30)$$

Judge the convexity and concavity of the profit function and maximize  $\Pi$ , we can get the optimal prices of integrated supply chain under different strategy combinations shown in Table. 4.

**Table.4** The optimal price of integrated supply chain

Strategy	I	Manufacturer	RD
R	$P_{Rr}^{(R,I)} = \frac{a}{2\alpha}$	$P_{Rr}^{(R,D)} = \frac{\alpha(1-\rho) + \beta p_a}{2(\alpha^2 - \beta^2)}$ $P_{Rd}^{(R,D)} = \frac{\alpha\rho + \beta(1-\rho)}{2(\alpha^2 - \beta^2)}$	No reasonable optimal price. (If you need the proofs, please connect the corresponding author)
Retailer		No reasonable optimal price. (If you need the proofs, please connect the corresponding author)	<p>When <math>\alpha &gt; 3\beta</math></p> $P_{Rr}^{(RD, RD)} = \frac{(\alpha - 2\beta)(1-\varepsilon)(1-\rho) + \beta(1-\theta)\rho + \varepsilon(1-\rho) + \theta\rho}{2(\alpha - 3\beta)(\alpha + \beta)}$ $P_{Rd}^{(RD, RD)} = \frac{(\alpha - 2\beta)(1-\theta)\rho + \beta(1-\varepsilon)(1-\rho) + \varepsilon(1-\rho) + \theta\rho}{2(\alpha - 3\beta)(\alpha + \beta)}$ $P_{Rr}^{(RD, RD)} = \frac{(\alpha - 2\beta)\varepsilon(1-\rho) + \beta(1-\varepsilon)(1-\rho) + (1-\theta)\rho + \theta\rho}{2(\alpha - 3\beta)(\alpha + \beta)}$ $P_{Rd}^{(RD, RD)} = \frac{(\alpha - 2\beta)\theta\rho + \beta(1-\varepsilon)(1-\rho) + (1-\theta)\rho + \varepsilon(1-\rho)}{2(\alpha - 3\beta)(\alpha + \beta)}$
RD	$P_{Rr}^{(RD,I)} = \frac{\alpha(1-\rho) + \beta p_a}{2(\alpha^2 - \beta^2)}$ $P_{Rd}^{(RD,I)} = \frac{\alpha\rho + \beta(1-\rho)}{2(\alpha^2 - \beta^2)}$		Otherwise, no reasonable optimal price.

If the manufacturer and retailer sell product on the basis of the optimal channel price, they can maximize the overall profits of supply chain. For coordinating multiple hybrid channel supply chain completely, the manufacturer may adjust his channel prices to be equaled to the optimal price. On the other hand, he also can use wholesale price to control retailer's channel price and make them equal to

the optimal value. So we let the optimal channel prices in Table.1 equal the optimal reaction functions obtained in Section 4, if the wholesale price  $\Omega$  can make the equations true, the complete coordination of supply chain can be achieved. The coordination wholesale prices are shown in Table.5.

**Table.5** The coordination wholesale prices

Strategy	Manufacturer		
	I	D	RD
Retailer	R $\Omega^{(R,I)} = 0$	$\Omega^{(R,D)} = \frac{\beta^2(1-\rho) + \alpha\beta\rho}{2\alpha(\alpha^2 - \beta^2)} a$	No coordination $\Omega$ .
	RD $\Omega^{(RD,I)} = 0$	No coordination $\Omega$ .	When $\alpha > 3\beta$ $\Omega^{(RD, RD)} = \frac{2\beta^2(1-\varepsilon)(1-\rho) + (1-\theta)\rho + \beta(\alpha - \beta)(\varepsilon(1-\rho) + \theta\rho)}{2(\alpha - 3\beta)(\alpha^2 - \beta^2)} a$ Otherwise, no coordination $\Omega$ .

Through the similar calculation, the coordination wholesale prices of same price strategy can be gotten. We show them in Table.6.

**Table.6** The coordination wholesale prices of same price strategy

Equilibrium Price	
(r, r)	$\Omega^{(r,r)} = \frac{(2\varepsilon - 1)a}{2\alpha}$
When $\alpha > 3\gamma/2\sqrt{2}$	
(r, rd)	$\Omega^{(r,rd)} = \frac{(6\alpha^2 - 4\gamma^2)(1-\varepsilon)(1-\rho) + (4\alpha^2 - 3\gamma^2)\varepsilon(1-\rho) + 2\alpha\gamma\rho}{\alpha(8\alpha^2 - 9\gamma^2)} a$
Otherwise, no coordination $\Omega$ .	
(rd, d)	No coordination $\Omega$ .
(Proofs are provided in Appendix. B)	
(rd, rd)	No coordination $\Omega$ .
(Proofs are provided in Appendix. B)	

## 7. Conclusion

In this paper, the authors divide the multiple hybrid channel supply chain into different types according to the different sales channel combination chosen by the manufacturer and retailer. Then, price competition between supply chains participants are discussed based on Stackelberg game rule. Our results show: (1). When the manufacturer and retailer use different channel price to compete, there is price equilibrium under strategy combination (R, I), (RD, I) and (R, D); If the system parameters satisfy certain conditions, the strategy combination (RD, D) has equilibrium price; There is no price equilibrium under strategy combination (R, RD) and (RD, RD). (2). When supply chain members use same channel price strategy, there is price equilibrium under strategy combination (r, r), (rd, d) and (rd, rd); If the system parameters satisfy certain conditions, the strategy combination (r, rd) has equilibrium price. (3). Using different channel price, the wholesale price change can coordinate supply chain under strategy combination (R, I), (RD, I) and (R, D), can't coordinate (R, RD) and (RD, D), and can coordinate (RD, RD) with certain parameters restrictions. (4). Using same channel price, the wholesale price change can coordinate (r, r), can't coordinate (rd, d) and (rd, rd), and can coordinate (r, rd) if system parameters satisfy certain conditions. This paper discusses the equilibrium prices of different structure multiple hybrid supply chain under the static demand environment and the equilibrium prices of dynamic demand should be the objective of further research.

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## References

- [1] B. Tedeschi, "Compressed data; Big companies go slowly in devising net strategy," *New York Times*, March 27, 2000.
- [2] A. Tsay, and N. Agrawal, "Channel conflict and coordination in the e-commerce age," *Production and Operations Management*, vol.13, no.1, pp.93–110, 2004.
- [3] G. W. Hua, S. Y. Wang, and T. C. E. Cheng, "Price and lead time decisions in dual-channel supply chains," *European Journal of Operational Research*, vol. 205, no. 1, pp.113–126, 2010.
- [4] K. Takahashi, T. Aoi, D. Hirotsu, and K. Morikawa, "Inventory control in a two-echelon dual-channel supply chain with setup of production delivery," *International Journal of Production Economics*, vol. 133, no. 2, pp. 403–415, 2011.
- [5] T. Boyaci, "Competitive stocking and coordination in a multi-channel distribution system," *IIE Transactions*, vol. 37, no. 5, pp. 407–427, 2005.
- [6] L. E. Cardenas-Barron, "Note on: concurrent pricing lot sizing for make-to-order contract production," *International Journal of Production Economics*, vol. 103, no. 1, pp. 449–450, 2006.
- [7] L. Salvietti, N. R. Smith, and L. E. Cardenas-Barron Leopoldo, "A stochastic profit-maximizing economic lot scheduling problem with price optimization," *European Journal of Industrial Engineering*, vol. 8, no. 2, pp. 193–221, 2014.
- [8] B. Sarkar, S. Saren, and H. M. Wee, "An inventory model with variable demand, component cost and selling price for deteriorating items," *Economic Modelling*, vol. 30, pp. 306–310, 2013.
- [9] S. S. Sana, "Optimal selling price and lotsize with time varying deterioration and partial backlogging," *Applied Mathematics and Computation*, vol. 217, no. 1, pp. 185–194, 2010.
- [10] S. Balasubramanian, "Mail versus mall: a strategic analysis of competition between direct marketers and conventional retailers," *Marketing Science*, vol. 17, pp. 181–195, 1998.
- [11] W. Y. K. Chiang, D. Chhajed, and J. D. Hess, "Direct marketing, indirect profits: a strategic analysis of dual-channel supply chain design," *Management Science*, vol. 49, no.1, pp. 1–20, 2003.
- [12] S. H. Chun, J.C. Kim, "Pricing strategies in B2C electronic commerce: analytical and empirical approaches," *Decision Support Systems*, vol. 40, pp. 375–388, 2005.
- [13] Y. Li, Z. Lin, L. Xu, and A. Swain, "Do the electronic books reinforce the dynamics of book supply chain market?" – A theoretical analysis, *European Journal of Operational Research*, vol. 245, no. 2, pp. 591–601, 2015.
- [14] G. E. Fruchter, C. S. Tapiero, "Dynamic online and offline channel pricing for heterogeneous customers in virtual acceptance," *International Game Theory Review*, vol. 7, pp. 137–150, 2005.
- [15] H. S. Ahn, I. Duenyas, and R. Q. Zhang, "Price competition between retailers manufacturer-owned stores," *University of California at Berkeley Working paper* 2002.
- [16] G. G. Cai, Z. G. Zhang, and Z. Michael, "Game theoretical perspectives on dual-channel supply chain competition with price discounts and pricing schemes," *International Journal of Production Economics*, vol. 117, no. 1, pp. 80–96, 2009.
- [17] D. Yao, and J. Liu, "Competitive pricing of mixed retailed and e-tail distribution channels," *Omega*, vol.3828, no.1, pp. 235–247, 2005.
- [18] J. Chen, H. Zhang, and Y. Sun, "Implementing coordination contracts in a manufacturer Stackelberg dual-channel supply chain," *Omega*, vol. 40, pp. 571–583, 2012.
- [19] W. Huang, and J. M. Swaminathan, "Introduction of a second channel: implications for pricing and profits," *European Journal of Operational Research*, vol. no. 1, pp. 258–279, 2009.
- [20] B. Dan, G. Xu, and C. Liu, "Pricing policies in a dual-channel supply chain with retail services," *International Journal of Production Economics*, vol.139, no. 1, pp. 312–320, 2012.
- [21] G. Xu., B. Dan, X. Zhang, and C. Liu, "Coordinating a dual-channel supply chain with risk-

- averse under a two-way revenue sharing contract,” *International Journal of Production Economics*, vol.147, no. A, pp. 171-179, 2014.
- [22] K.-Y. Chen, M. Kaya, and O. Ozalp, “Dual sales channel management with service competition,” *Manufacturing and Service Operations Management*, vol. 10, no. 4, pp. 654–675, 2008.
- [23] L. Ren, Y. He, and H. Song, “Price and service competition of dual-channel supply chain with consumer returns,” *Discrete Dynamics in Nature and Society*, Vol.2014, pp.1-10.
- [24] Y. -C. Chen, S.-C. Fang, and U.-P. Wen, “Pricing policies for substitutable products in a supply chain with Internet and traditional channels,” *European Journal of Operational Research*, vol. 224, no. 3, pp. 542–551, 2013.
- [25] S. Panda, N. M. Modak, S. S. Sana, and M. Basu, “Pricing and replenishment policies in dual-channel supply chain under continuous unit cost decrease,” *Applied Mathematics and Computation*, vol. 256, pp. 913–929, 2015.
- [26] M. Khouja, S. Park, and G. G. Cai, “Channel selection and pricing in the presence of retail-captive consumers,” *International Journal of Production Economics*, vol. 125, no. 1, pp. 84–95, 2010.
- [27] T. Li, J. Ma, and L. Sun, “Complexity uncertainty analysis of dynamic in a dual-channel energy supply chain model with heterogeneous retailers,” *Mathematical Problems in Engineering*, vol. 2015, pp. 1-10.
- [28] H. Kurata, D. Q. Yao, and J. J. Liu, “Pricing policies under direct vs. indirect channel competition and national vs. store brand competition,” *European Journal of Operational Research*, vol. 180, no. 1, pp. 262–281, 2007.
- [29] L. Hsiao, Y.-J. Chen, “The perils of selling online: manufacturer competition, channel conflict, and consumer preferences,” *Marketing Letters*, vol. 24, no. 3, pp. 277–292, 2013.
- [30] T. Li, and J. Ma, “Complexity analysis of the dual-channel supply chain model with delay decision,” *Nonlinear Dynamics*, vol. 78, no. 4, pp. 2617-2626, 2014.