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Multi-leadership in Closed Loop Supply Chain Based on Dual-channel

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Abstract. With the implementation of the Expanded Production Responsibility Framework (EPR) and the lack of resources, people turned their attention to the closed-loop supply chain (CLSC) as a solution. In the practical application of the closed-loop supply chain, companies have adopted a dual-channel sales model for online direct sales and offline retail sales. Based on the actual situation, this paper establishes three Stackelberg leader CLSC models with three-echelon, based on the dual-channel models. These models includes manufacturer-led dual-channel CLSC, retailer-led dual-channel CLSC, collector-led dual-channel CLSC and centralized CLSC. This paper is aimed to find out the optimal solution on each various Stackelberg leading models. Unlike expectations, collector-led dual-channel CLSC is not so good as other models, it even can't lead to high collection effort. The customers' preference to online supply chain increases in certain range, which can make excellent performance of total dual-channel supply chain. In addition, too much preference of online sales in manufacturer-led dual-channel can lead to only existence of online sales.

1. Introduction

According to the Allen MacArthur Foundation report, if China turns to a circular economy, enterprises and households will save 32 trillion yuan by 2030. It also reduces air pollution caused by tiny particles by 10% and greenhouse gas emissions by 11%[1]. In the 13th Five-Year Plan, China has increased its share of renewable energy, and has improved its product design and recycling by prohibiting the import of 24 types of foreign waste and expanding the Extended Producer Responsibility (EPR) framework. EPR is defined by the OECD as an environmental policy approach in which producer has the responsibility for products extends to the post-consumer phase of the product life cycle. In order to obtain the dual benefits of online channels and offline channels (dual channels), many companies often use direct online and offline stores to sell[2]. Actually, the specific business strategies of different companies are different. [3, 4]. Sun's servers, storage devices, and workstations are sold in a combination of online direct sales and offline retail sales channels. Remanufacturing products and new products in this model have consistent quality assurance services and three-pack service, saving 20% of the cost for the company [5]. Gan, et al.[6] introduced the improvement factor of the demand function in the paper. Giri, et al.[7] considered the dual channel of recycling and sales of products in the closed-loop supply chain. Recycling dual-channels means that some are recycled directly from the manufacturer and the other is recycled through a third party. Arya, et al.[8]

found that in the dual channel, the entry of the supplier will have a certain erosion effect on the retailer, but the retailer will benefit from the lowering of the wholesale price by the supplier.

For remanufacturing companies that use the dual-channel model, they can achieve cost savings and create a positive corporate image of green, energy-efficient and emission-reducing. The research problem is slightly limited in two-echelon dual-channel CLSC, our paper sets three-echelon dual-channel CLSC with a single manufacturer, a single retailer and a single collector. Taleizadeh, et al.[9] considered a two-echelon dual-channel CLSC with manufacturer-led. Because of the continuous refinement of the division of labor, the traditional two-echelon closed-loop supply chain model will certainly expand into three-echelon closed-loop supply chain model[10].The collector as a separate party does it[11]. For traditional manufacturing models, manufacturers often have the most capital and technical advantages, thus they have pricing priority in building models. Savaskan, et al.[10]sets up a classic closed-loop supply chain model with a manufacturer and a retailer, the former is Stackelberg leader. Nowadays large retailers appears, such as Wal-Mart, Carrefour and other retail supermarkets, facing with lots of small manufacturers. Thus retailers obtain the preferential pricing power of wholesale prices by letting them compete with each other [12]. Xiao, et al.[13] investigated when the indirect channel sales of standard products in the retailer-Stackelberg model, and direct sales of customized products.

With the diversification of business models, the advantages of all parties are no longer solidified. [14]. For example, love recycling websites, online recycling of used mobile phones, tablets, laptops, smart digital products, etc. They have fixed recycling and resale channels, so they have priority pricing rights for recycled products in the closed-loop supply chain[5]. Savaskan and Van Wassenhove[15] studied the situation of one manufacturer and two retailers, and this the two retailers are in a competitive relationship. Esmaeili, et al.[16] considered a non-cooperative game to analyse the behaviour between the buyer and the seller. From the papers reviewed above, we can see that the relationships of buyers and sellers is very popular in research, Stackelberg model is one main sections of these papers. However, the articles above principal focus on forward supply chain instead of reverse supply chain.

The remainder of the paper is organized as follows. In section 2, the research problem and related assumptions is introduced. In section 3, multi-leadership CLSC will be provided and solved to find optimal solution. In section 4, we compare profit and optimal decision among three multi-leadership models. In section 5, we conclude and outline the results and future research of this work.

2. Model and assumption

Considering such a two-channel CLSC, there are three parties, namely retailer (R), manufacturer (M) and recycler (C). Consumers can purchase remanufactured products and new products from both online direct sales channels and offline retailer sales channels. The remanufactured products of these two channels are sold at the same price[9]. when δ symbolizes the degree of consumers who prefer purchasing in direct channel and 1-δ expresses the percentage of consumers who prefer purchasing though retail channel. In this way, the demand for direct e-commerce channels and the demand for retail channels can be simplified as $D_o = \delta a - bp$ and $D_r = (1 - \delta)a - bp$. respectively[9].

The recycler is responsible for remanufacturing the product from the customers with the product return rate of $\tau(0 \leq \tau \leq 1)$[10]. For recyclers, the total cost of the collector is $c_c(\tau) = \frac{1}{2}c_L\tau^2 + A\tau(D_o + D_r)$. A represents the unit cost paid by the collector in order to obtain the used product. I indicates the investment required for recycling activities, c_L refers to the scale factor. The manufacturer pays a certain amount of unit reward n from the recycler to obtain raw materials for remanufacturing, and then produces remanufactured products and new products. Total manufacturing cost per unit for the manufacturer is $c(\tau) = c_m(1 - \tau) + c_r\tau$, and $c_m - c_r > n > A$. to make it meaningful and profitable to produce manufactured products. c_m denotes the unit cost of manufacturing a new product, c_r denotes the unit cost of remanufacturing a returned product into a new one. The retailer obtains the product from the manufacturer at the price of the

unit wholesale price w, and sets a uniform retail price p for the new product and the reworked product. Suppose they are the same in quality and appearance, and consumers can't distinguish them and lead to differential pricing.

The following explains the meaning of the symbols that will be used. $w_i, n_i, \tau_i, p_i, D_i$ symbolizes unit wholesale price, the unit transfer price of a remanufactured product from the retailer, the product return rate, retail price, total demand, respectively. (i=M,C,R,T. symbolizes manufacturer-led, collector-led, retailer-led, centralized dual-channel CLSC, respectively). D_{oi}, D_{ri} represents demand for online direct channel and retailer channels, respectively. Π_i^j (j= M,C,R;T. symbolizes manufacturer-led, collector-led, retailer-led, centralized dual-channel CLSC, respectively, i=M,C,R, represents manufacturer, collector and retailer, respectively)

3. Multi-leadership dual-channel CLSC

3.1. M-LED DUAL-CHANNEL CLSC

In this case, the manufacturer is the leader of Stackelberg, a model structure that is common when studying closed-loop supply. Recycling work is all outsourced to collector. The manufacturer first determines the retail price w and the transfer price n paid to the collector, and then the retailer decides the retailer price p on the market. Although there are two sales channels in this article, manufacturers also participate in sales activities, but only retailers have the right to pricing. Finally, the collector decides the collection rate τ of recycled products from consumers. The model structure is shown in Figure 1. The solid arrow indicates the forward supply chain flow channel, and the dotted arrow indicates the reverse supply chain flow channel.
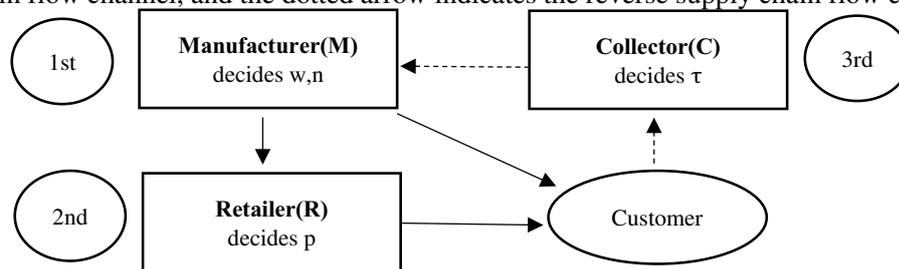

Figure 1 Manufacturer-led dual-channel CLSC

The profit of collector is, $\Pi_C^M(\tau) = (n_M - A)\tau_M(D_{oM} + D_{rM}) - c_L\tau_M^2/2$ (1)

The profit of retailer is $\Pi_R^M(p) = (p_M - w_M)D_{rM}$ (2)

The profit of manufacturer is

$\Pi_M^M(w,n) = w_M D_{rM} + p_M D_{oM} - (1 - \tau_M)c_m(D_{oM} + D_{rM}) - \tau_M c_r(D_{oM} + D_{rM}) - n_M\tau_M(D_{oM} + D_{rM})$ (3)

The solution direction of the model is the reverse direction of the decision order, then the solution can be discussed below. There are two situations:

a) when $\delta^1 < \delta < \delta^2$, $\delta^2 = \frac{3ac_L - 2bc_m c_L - ab\Delta^2}{2(2ac_L - ab\Delta^2)}$, $\delta^1 = \frac{3ac_L + 2bc_m c_L - ab\Delta^2}{2(4ac_L - ab\Delta^2)}$. In order to make $D_{oM} > 0, D_{rM} > 0$ established, At this case, online sales and offline sales exist simultaneously.

b) If $\delta > \delta^2$, the optimal decisions of manufacturer, retailer and collector are. At this case, All sales will be concentrated in the network direct sales channel, retailers no longer sell products.

3.2. C-LED DUAL-CHANNEL CLSC

China's current large recycling companies include: recycling treasures, love recycling and so on. A model based on this actual situation is collector-led dual-channel CLSC. Because the company is large in scale and has a unique recycling sales channel, the collector has more rights. It decides collection rate τ and the

transfer price n paid to the collector. Then the manufacturer decides wholesale price w, retailer decides retailer price p finally.

The profit of retailer is $\Pi_R^C(\text{p}) = (p_C - w_C)D_{rC}$ (4)

The profit of manufacturer is

$\Pi_M^C(\text{w}) = w_C D_{rC} + p_C D_{oC} - (1 - \tau_C)c_m(D_{oC} + D_{rC}) - \tau_C c_r(D_{oC} + D_{rC}) - n_C \tau_C(D_{oC} + D_{rC})$ （5）

The profit of collector is $\Pi_C^C(n, \tau) = (n_C - A)\tau_C(D_{oC} + D_{rC}) - c_L \tau_C^2/2$ (6)

3.3. R-LED DUAL-CHANNEL CLSC

Existing retailer leadership models, such as Wal-Mart. Retailer firstly decides wholesale price w and manufacturer will decide retailer price p and the transfer price n paid to the collector. The collector decides collection rate τ. The reason why retailer decides w and retailer decides p, because of the unique of dual-channel unified pricing. The manufacturer can hold more information than retailer to decide it. which can be revealed in reality, the milk manufacturer sets unified retailer price in offline Wal-Mart sales and Taobao online sales. Wal-Mart can set w by choosing preferred small manufacturer who give lowest price.

The profit of collector is $\Pi_C^R(n, \tau) = (n_R - A)\tau_R(D_{oR} + D_{rR}) - c_L \tau_R^2/2$ (7)

The profit of manufacturer is

$\Pi_M^R(\text{w}) = w_R D_{rC} + p_R D_{oC} - (1 - \tau_R)c_m(D_{oR} + D_{rR}) - \tau_R c_R(D_{oR} + D_{rR}) - n_R \tau_R(D_{oR} + D_{rR})$ (8)

The profit of retailer is $\Pi_R^R(\text{p}) = (p_R - w_R)D_{rR}$ (9)

4. comparison under multi-leadership

4.1. COMPARISON ON OPTIMAL DECISION UNDER MULTI-LEADERSHIP

a) $n_M = n_R < n_c$, Both the R-led and M-led dual-channel CLSC set consistent transfer price. The transfer price in C-led dual-channel CLSC is the biggest. Transfer price in any models is not influenced by δ, the customers preference toward the direct channel.

 b) By calculation, there is $\frac{\partial \tau_M}{\partial \delta} > 0, \frac{\partial \tau_C}{\partial \delta} > 0, \frac{\partial \tau_R}{\partial \delta} > 0, \frac{\partial \tau_T}{\partial \delta} = 0$. To compare τ in different models, set $\delta = 0.5, \tau_T > \tau_R > \tau_C = \tau_M$. there is $\frac{\partial w_M}{\partial \delta} > 0, \frac{\partial w_C}{\partial \delta} > 0, \frac{\partial w_R}{\partial \delta} > 0$, To compare w in different models, set $\delta = 0.5, w_C > w_M > w_R$. $\frac{\partial p_M}{\partial \delta} < 0, \frac{\partial p_C}{\partial \delta} < 0, \frac{\partial p_R}{\partial \delta} < 0, \frac{\partial p_T}{\partial \delta} = 0$, To compare p in different models, set $\delta = 0.5$, $p_C > p_M > p_R > p_T, D_{oR} > D_{oM} > D_{oC}, D_{rR} > D_{rM} > D_{rC}$..

4.2. NUMERICAL ANALYSIS OF PROFIT UNDER MULTI-LEADERSHIP

Set a=300,b=2,$c_m = 30, c_r = 15$,A=5,$\Delta = 10, c_L = 2000$ and $\delta \epsilon [0.4559, 0.5625]$ to make dual-channel established.

   (1) As Figure 2 below, the improve of customers' preference δ to online channel can lead to increase of manufacturer's profit in M-led and R-led models. The increase of δ can lead manufacturer's profit in C-led model increase first and then decrease. When dual-channel exits, relatively low δ can lead to $\Pi_M^M > \Pi_M^C > \Pi_M^R$, and relatively high δ can lead to $\Pi_M^M > \Pi_M^R > \Pi_M^C$.

   (2) $\Pi_R^R > \Pi_R^M > \Pi_R^C$, with the increase of δ, the profit of retailer decreases in three multi-led CLSC. Due to the length of the article, the diagram is omitted here. It's understandable retailer can have the most profit in R-led model. What's more, the profit of retailer in M-led model is greater than C-led model.

(3) $\Pi_C^C > \Pi_C^R > \Pi_C^M$, with the increase of δ, the profit of collector increases in three multi-led CLSC. Due to the length of the article, the diagram is omitted here. Collector can achieve most profit in C-led model. And the profit of collector in R-led model is larger than in M-led model.

(4) As Figure 3 below, the total profit in three decentralized models increases with increase of δ. And δ has no impact on total profit in centralized model. When dual-channel exits, relatively low δ can lead to $\Pi_T^R > \Pi_T^M > \Pi_T^C$, and relatively high δ can lead to $\Pi_T^M > \Pi_T^R > \Pi_T^C$. That is to say, if customers not too keen on online channel, R-led model is preferred in supply chain, otherwise M-led model is a better choice for supply chain members. What's more, from the consideration of whole supply chain, C-led model is the least preferred choice.
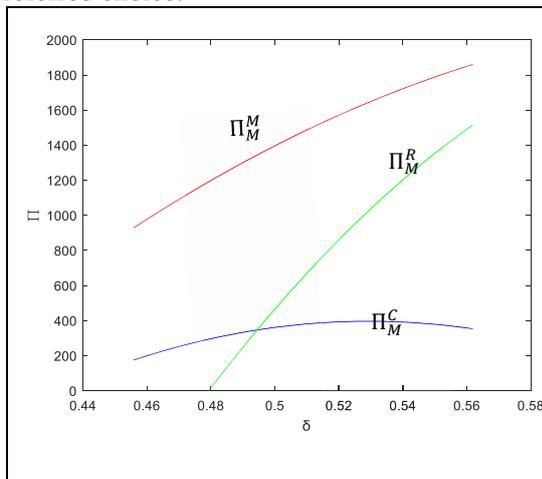

Figure 2 profit of manufacturer under multi-leadership with δ
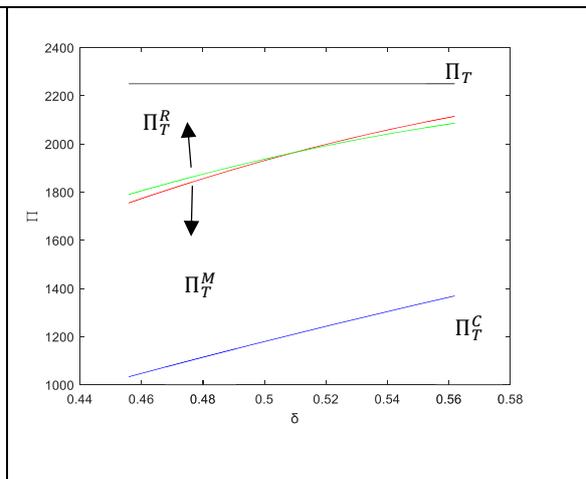
Figure 3 profit of total under multi-leadership with δ

5. conclusion

This paper researches on three-echelon dual-channel CLSC under multi-leadership. There already exists many researches focusing on competition and cooperation among members in Stackelberg model. With the introduction of dual channels, the relationship will be more complexed. Different leadership can influence the optimal decision of wholesale price, retail price, transfer price and collection rate. The paper found that if the preference to online channel increase to some extent in appropriate range existing dual-channel, choosing M-led model is the best solution to gain most total profit, otherwise R-led model. In conclusion, C-led model is the worst choice under any situation. From the perspective of improving collection rate, R-led model is the best. For it can weaken the double marginalization problem in forward and reverse channels , the closer to market, the more effective it is, so R-led is the best. Under M-led model, if the preference to online channel is adequate enough can make it possible for the supply chain only sale goods through online channel. If the dual-channel exist, the increase of preference to online channel can improve the total profit of this supply chain. From a management perspective, It's advisable to improve customers' preference to online channel. Even online and offline prices are consistent, the preference to online channel can weaken "repeated double marginalization" and members in supply can gain more profits.

There still some constrains in this paper, although this paper is well-supported by literatures and also well-motivated by various industrial practices. For future research, some constrains can be ease. (1)Demand function may be nonlinear; (2) There exists more than one manufacturer , retailer and collector. They can

compete and collaborate with each other: (3) The quality of used products may be different, and how it influence decision.

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