AMSE JOURNALS-2016-Series: Advances A; Vol. 59; N°1; pp 30-46
Submitted July 2016; Revised Oct. 15, 2016, Accepted Dec. 10, 2016

Research on Synergetic Pricing Strategy of Cloud-Closed Loop Supply Chains

*Minglin Jiang, **Xiaowei Lin, ***Haiping Ren

*School of Business, Minnan Normal University, P. R. China, Zhangzhou, (heatherj@163.com)
**School of Business, Minnan Normal University, P. R. China, Zhangzhou, (lxw949@163.com)
* School of Software, Jiangxi University of Science and Technology,P. R. China, Nanchang, (chinarhp@163.com)

Abstract

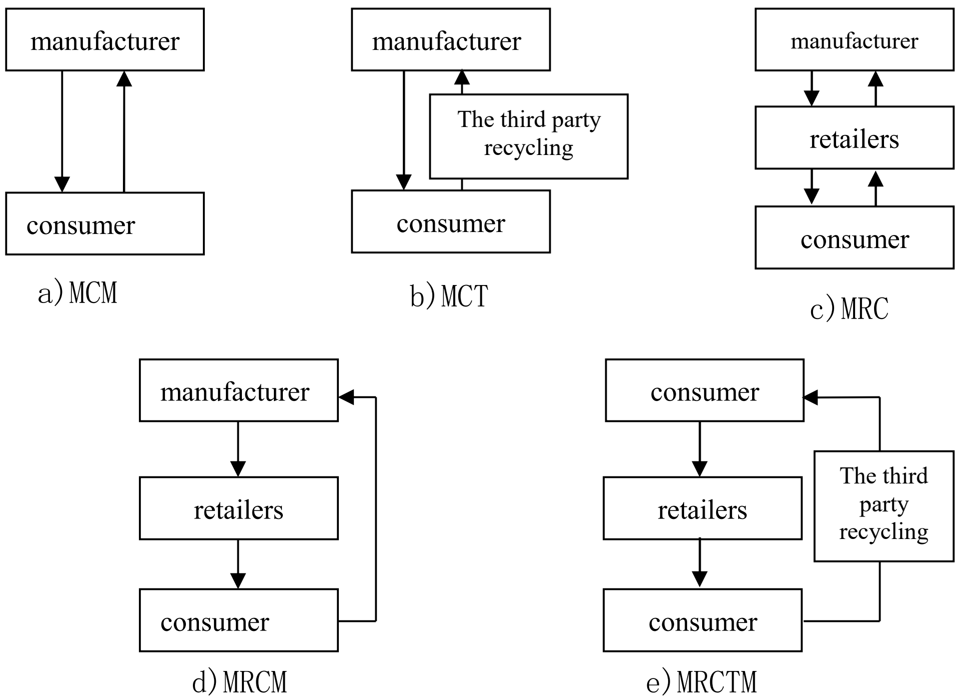
Combining cloud computing technology with closed-loop supply chain, this paper develops a new algorithm of pricing mechanism of closed-loop supply chain. A structural model of cloud closed-loop supply chain (cloud-CLSC) is built first to explore its new functional attributes. Stackelberg master-slave game model and optimization theory are applied to discuss and compare the synergetic pricing strategy between the centralized and the decentralized decision models of cloud-CLSC, during which the optimal pricing strategy of the enterprise clusters in the corresponding nodes of cloud-CLSC is identified, and the profits gained in each node, as well as the aggregate profits are evaluated. It is suggested that the improved pricing mechanism of the decentralized decision model of cloud-CLSC presented here helps to obtain more aggregate profits than those from the centralized one. Finally, numerical simulation analysis is applied to prove the validity of the theorem.

Keywords

cloud computing; cloud closed-loop supply chain; synergy; pricing mechanism

1. Introduction

Closed loop supply chains means the integrity of the supply chain cycle, which contains forward logistics and reverse logistics [1]. Some scholars believe that closed-loop supply chain model includes manufacturers dominate supply chain model and sellers dominate supply chain model. Other scholars believe that closed-loop supply chain model was made up of M model, M-R model, M-T model and M-R-T model. M model refers to production and sales integration and recycled by retailers, M-R model refers to the production and marketing of separation and recycled by retailers, M-T model refers to the production and sales integration and recycled by a third party, M-R-T model refers to the production and marketing of separation and recycled by a third party [2]. Some scholars view it from the perspective of channel participants. In their opinions, closed-loop supply chain include manufacturers, retailers, customer and the Third Party reverse logistics (Third Party), who can be integrated into five kinds of channel model[3]: MRCRM model, MRCTM model, MRCM model, MCTM model and MCM model. They are illustrated in figure 1.



Finger 1. Five kinds of typical structure models of CLSC

Cloud computing can improve the supply chain. Many scholars focus on the research on how cloud computing are changing the information flow in supply chain system [4]. For example, reference [5] used cloud computing to construct the operation model of virtual information center. Reference [6] discussed the cloud supply chain information synergy and the risks arise. Reference [7] found the specific functions of cloud computing in the supply chain, and built on remanufacturing closed-loop supply chain cloud manufacturing service platform. Reference [8] found that the use of cloud computing technology in supply chain, its structure, function, attribute, pricing mechanism and profits having its own characteristics. Based on cloud computing technology, some scholars have built manufacturers dominant Stackelberg game model of two-stage supply chain. They find that each node enterprises in cloud supply chain get more profits than that in the traditional supply chain, and the range of cloud service charge that supply chain members are willing to pay.

Similarly, closed-loop supply chain with cloud computing technology is becoming an inevitable trend. The combination of cloud computing and the closed-loop supply chain make synergetic management as the core, which helps to achieve synergistic effect for the target, to revitalize the stock of manufacturing resources, to accomplish green manufacturing and competitiveness of the enterprises,. Therefore, in this paper, we build the cloud closed-loop supply chain structure model, analyze the optimal pricing strategy, and explore the functional properties and profits of cloud closed-loop supply chain.

2. Cloud Closed-loop Supply Chain

2.1 Cloud computing technology combined with closed-loop supply chain

In the aspect of management ideas, closed-loop supply chain is made up of many economic subjects. Its mesh structure is made up of multiple nodes. It needs systematic point of view to optimize closed-loop supply chain, to meet market demand, to coordinate the relationship among the enterprises in closed-loop supply chain. Reference [9] pointed out that cloud computing needs to integrate thinking, meeting the personalized requirements of users in a timely and effectively manners, making research object to achieve synergetic dynamic optimization. So both closed-loop supply chain and cloud computing are involved in the synergetic problem.

2.2 Definition

In this paper, definition of cloud closed-loop supply chain is that, cloud computing, Internet, Internet of things, sensor network technology and so on are connected to build a cloud platform, and that cloud computing combined with closed-loop supply chain enables closed-loop supply chain to be "cloud". This article takes MRCTM (manufacturers-retailers–customer-the Third Party reverse logistics- manufacturers) structure of cloud closed-loop supply chain as an example, as shown in figure 2.

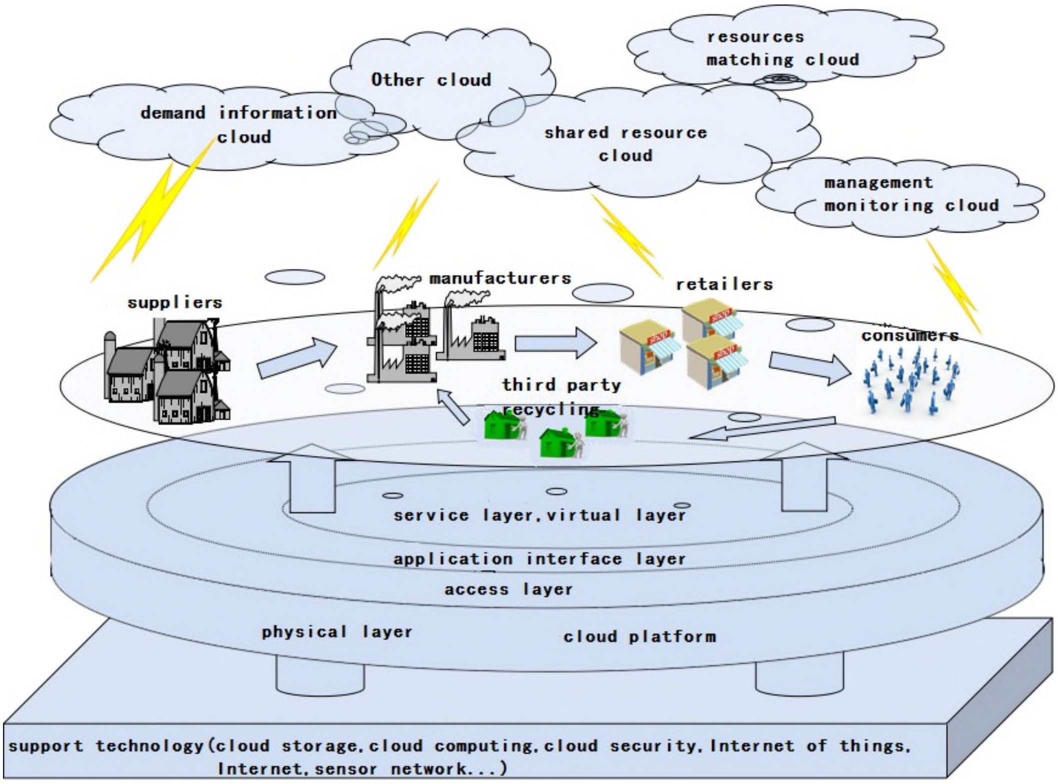


Figure 2. Structure of cloud closed-loop supply chain

2.3 Attribute

Cloud closed-loop supply chain has different attributes from traditional closed-loop supply chain, specifically as follows.

Step 1. Enterprises cluster.

Cloud closed-loop supply chain can provide information integration services for enterprises scattered around the world, making enterprises of distributed networked to be enterprises cluster.

Step 2. Information integration.

Cloud closed-loop supply chain is not only guaranteed to independent original information system of each enterprise in the supply chain, but also breaks through the boundaries of time, place and organizations to integrate information, realizing information resources sharing and communication among cloud closed-loop supply chain subjects.

Step 3. The agile reaction.

Cloud closed-loop supply chain enhances the sensitivity of the enterprise to market end demand, meeting rapid response to customer demand, completing dynamic matching requirements to be synergetic development, enhancing enterprise market competence.

2.4 Function

Each node of cloud closed-loop supply chain is not only a single enterprise, but enterprise cluster. Relationship between manufacturers and end users of it is not only "one to many", similarly, the relationship between recycling companies and manufacturers is not only "many to one", the relationship among manufacturers, recycling companies and consumers are "many to many". It makes system resources to be well rationally matched and scheduled.

Information flow in the chain is no longer passed a layer upon layer, system information is collected in the "cloud" pool. Through the analysis and integration of information, enterprises in cloud closed-loop supply chain integrate resources. Each node in it will match information accurately, enable the intelligent use of resources. It can satisfy different subject in it for personalized needs of manufacturing and remanufacturing, achieving a balance between supply and demand. Within the shortest possible time and the shortest channel, renewable resources are recycled and sent to the corresponding manufacturing enterprises, then reproduction products are sent to related retail market.

Cloud closed-loop supply chain is a system of highly shared resources, rapid response and optimal cost. It makes resources of forward and reverse supply chain to be effectively integrated, and information flow, cash flow, logistics are to be well coordinated and integrated. Enterprises in supply chain are also highly cooperative. Social resources are distributed on demand in the chain, in which personalized service of high efficiency, high quality and low cost for users are provided to improve the comprehensive utilization of renewable resources.

3. Model

In the system of cloud-CLSC, there are such components as manufacturers, retailers and third-party recycling enterprises. The three main parities mentioned above have become enterprise cluster and lead to three courses. The first is the third-party recycling enterprises which recycle, classify and sort end-of-life products as raw materials for remanufacturing from consumer. The second is the third-party recycling enterprises which deliver them on-demand to manufacturers, the leader of cloud-CLSC through reverse logistics of CLSC. The third is the manufacturers who deliver their manufacturing and remanufacturing products to retailers for selling.

3.1 Definition of Parameters

Table 1. Definition of Parameters

Parameter	Definition
M	manufacturing enterprise cluster
S	retailing enterprise cluster
R	third-party recycling enterprise cluster
Q	market demand
A	market size
B	impacting coefficient of manufacturing and remanufacturing product price to demand
G	recycling volume of end-of-life product by third-party recycling enterprises
h	impacting coefficient of recycling price to recycling volume
k	free recycling volume from consumers when recycling prices is 0
w	unit wholesale price made by manufacturers for retailers (decision variables)
p	unit selling price made by retailers (decision variables)
b	unit transfer price of end-of-life product made by manufacturers for third-party recycling enterprise (decision variables)
pr	recycling price of end-of-life product made by third-party recycling enterprises for consumers(decision variables)
C1	unit manufacturing cost of manufacturers
C2	unit remanufacturing cost of manufacturers
Cs	unit selling cost of retailers including inventory cost, transportation cost etc.
Cy	unit product required for cloud service
π	total profit of the cloud-CLSC
π_M	total profit of manufacturing enterprise cluster
π_S	total profit of retailing enterprise cluster
π_R	total profit of third-party recycling enterprise cluster

3.2 Hypothesized Model

(1) In order to simplify the model, it assumes the unit selling price of manufacturing and remanufacturing product are the same as p.

(2) Based on cloud-CLCS with powerful function of collection and integrated analysis for demand information, it only studies the impact of price on demand, and assumes there is a demand function:

$Q = 1 - BP$

(3) It assumes that producing capacity of the manufacturing enterprise cluster in the upper of cloud-CLSC is unlimited and could meets all the individual demand of terminal user. In these conditions, it also assumes there is relationship of unit cost of manufacturing $C_1$and unit cost remanufacturing C_2: $C_1 > C_2$.

(4) Because enterprises in cluster of cloud-CLSC are many to many relationships, it is easy to match the recycling the end-of-life products of consumers for the manufacturing enterprises on-need. So it assumes all the end-of-life products recycled by the third-part enterprises could be used to remanufacture and delivery reasonably to the corresponding manufacturers. In order to ensure that the remanufacturing have good gain, the transfer price b given by manufacturers for the third-part enterprises meets $0 < b < C_1 - C_2$.

(5) In order to ensure that the third-part recycling enterprise have good gain, it assumes recycling volume function $G = k + hp_r, p_r < b < C_1 - C_2$.

(6) All the main body of cloud-CLSC could get information on-demand and must pay the corresponding cloud service fee. So it assumes that the main body can obtain all of the required information and make the pricing decision based on market information from cloud platform.

3.3 Model analysis

3.3.1Model I: Analysis of centralized decision model of cloud-CLSC

The manufacturing enterprise cluster with core manufacturing technology becomes the leader of cloud-CLSC, which can choose purchasing materials from suppliers of raw materials for manufacturing, and the end-of-life products from third-part recycling enterprises for remanufacturing. According to the specific market demand of consumers, downstream of cloud-CLSC retailers get products from the manufacturers to sell. Model I is a centralized decision model of cloud-CLSC that aims to the optimal profits of the whole chain. It is not the problem of "double marginal price". Thus, the cloud-CLSC likes a virtual organization taking the manufacturing enterprise cluster, retailing enterprise cluster and third-part recycling enterprise cluster as a whole. They decide the pricing strategy together.

Profit functions of each member on cloud-CLSC are as follows:

$$\pi_M^I = (w - C_Y)Q - (C_2 + b)G - G_1(G - Q)$$

$$\pi_S^I = (p - w - C_s - C_Y)Q$$

$$\pi_R^I = (b - pr - C_Y)G$$

$$\begin{aligned}\pi^I &= \pi_M^I + \pi_S^I + \pi_R^I \\ &= (p - C_1 - C_s - 2C_Y)Q + (C_1 - pr - C_2 - C_Y)G\end{aligned}$$

In the condition of centralized decision, cloud-CLSC total profit π^1 is unrelated to wholesale price W and transfer price b, only depends on producing cost, selling cost, cloud service, recycling price and selling price. The wholesale price W and a transfer price b just decide the benefit distribution among the members of cloud-CLSC. So it only needs decide the optimal price of selling and recycling. The centralized decision model of cloud-CLSC are as follows：

$$\begin{cases}(p^I, pr^I) \in \arg\max \pi^I(p, pr) \\ \qquad = (p - C_1 - C_S - 2C_Y)Q + (C_1 - pr - C_2 - C_Y)G \\ \quad s.t. Q > G > 0\end{cases}$$

Among them, $p, pr \geq 0$

$$\begin{aligned}\pi^I &= (p - C_1 - C_S - 2C_Y)Q + (C_1 - pr - C_2 - C_Y)G \\ &= -Bp^2 + (A + BC_1 + BC_S + 2BC_Y)p - hpr^2 + (hC_1 - k - hC_2 - hC_Y)pr \\ &\quad + (C_1 - C_2 - C_Y)k - (C_1 + C_S + 2C_Y)A\end{aligned}$$

In order to maximize the profits of the whole cloud-CLSC, it must meet $\dfrac{\partial \pi^{\mathrm{I}}}{\partial p} = 0$, $\dfrac{\partial \pi^{\mathrm{I}}}{\partial p_r} = 0$. Available, the optimal pricing decision of cloud-CLSC is:

$$\begin{cases}p^I = \dfrac{A + BC_1 + BC_S + 2BC_Y}{2B} \\ pr^I = \dfrac{hC_1 - k - hC_2 - hC_Y}{2h}\end{cases}$$

Taking p^I, p_r^I in $\pi^I(p, pr)$, it can get the max profit of cloud-CLSC while making centralized decision. The function is:

$$\pi^{I*} = \frac{(A - BC_1 - BC_S - 2BC_Y)^2}{4B} + \frac{(k + hC_1 - hC_2 - hC_Y)^2}{4h}$$

3.3.2 Model II: Analysis of decentralized decision model of cloud-CLSC

When making Decentralized decision in system-CLSC, it is Stackelberg type game which considers the manufacturing enterprise cluster as leader, while the retailing enterprise cluster and the third-part recycling enterprise cluster as the followers. There is no leading relationship between third-part recycling enterprise cluster and retailing enterprise cluster, which can be seen as a static game. All the main body of cloud-CLSC makes pricing decision according to maximize itself profits principle. The decentralized pricing decisions process of cloud-CLSC is: Manufacturing enterprise cluster according to the market demand, gives the wholesale price w and the transfer price b; The retailing enterprise cluster according to wholesale prices and market information, makes the selling price p; Third-part recycling enterprise cluster makes recycling price p_r based on transfer price b and market information.

Profit functions of member in cloud-CLSC are as follows:

$$\pi_M^{II} = (w - C_Y)Q - (C_2 + b)G - C_1(G - Q)$$

$$\pi_S^{II} = (p - w - C_S - C_Y)Q$$

$$\pi_R^{II} = (b - pr - C_Y)G$$

$$\begin{aligned}\pi^{II} &= \pi_M^{II} + \pi_S^{II} + \pi_R^{II} \\ &= (p - C_1 - C_S - 2C_Y)Q + (C_1 - pr - C_2 - C_Y)G\end{aligned}$$

Profit function of manufacturing enterprise cluster is:

$$\pi_M^{II} = (w - C_Y - C_1)\left[A - Bp(w)\right] - (C_2 + b - C_1)G$$

Using the method of inverse derivation to solve Stackelberg model of cloud-CLSC, model should meet:

$$\begin{cases} \max \pi_M^{II}(w,b) = (w - C_Y - C_1)[A - Bp(w)] - (C_2 + b - C_1)G \\ s.t \begin{cases} p \in \arg\max \pi_S^{II}(p), \forall Q > 0 \\ pr \in \arg\max \pi_R^{II}(pr), \forall G > 0 \end{cases} \end{cases}$$

From $\dfrac{\partial \pi_S{}^{II}(p)}{\partial p} = 0$, $\dfrac{\partial \pi_R{}^{II}(pr)}{\partial pr} = 0$,it could get:

$$\begin{cases} p = \dfrac{A + (w + C_S + C_Y)B}{2B} \\ pr = \dfrac{bh - k - hC_Y}{2h} \end{cases}$$

Taking p, p_r into π_M^{II}, it can get:

$$\begin{cases} w = \dfrac{A + BC_1 - BC_S}{2B} \\ b = \dfrac{C_1 h + C_Y h - k - C_2 h}{2h} \end{cases}$$

Taking w and b into p, pr, it can get the optimal pricing decision:

$$\begin{cases} p^{II} = \dfrac{3A + BC_1 + BC_S + 2BC_Y}{4B} \\ pr^{II} = \dfrac{hC_1 - hC_2 - hC_Y - 3k}{4h} \end{cases}$$

In the end of the pricing decision, it takes w, b, p^{II}, p_r^{II} into profit function of members in cloud-CLSC and gets:

$$\pi_M^{II*} = \frac{(A - BC_1 - BC_S - 2BC_Y)^2}{8B} - \frac{(C_2 + b - C_1)(k + hC_1 - hC_Y - hC_2)}{4}$$

$$\pi_S^{II*} = \frac{(A - BC_1 - BC_S - 2BC_Y)^2}{16B}$$

$$\pi_R^{II*} = \frac{(C_1 h - C_2 h + k - C_Y h)^2}{16h}$$

$$\pi^{II*} = \frac{3(A - BC_1 - BC_S - 2BC_Y)^2}{16B} + \frac{(C_1 h - C_2 h + k - C_Y h)^2}{16h} - \frac{(C_2 + b - C_1)(k + hC_1 - hC_Y - hC_2)}{4}$$

3.4 Model comparison

3.4.1 Comparisons of model I and II

Doing subtraction between π^{I*} and π^{II*}, it can get:

$$\pi^{I*} - \pi^{II*} = \frac{(A - BC_1 - BC_S - 2BC_Y)^2}{16B} + \frac{3(C_1 h - C_2 h + k - C_Y h)^2}{16h} + \frac{(C_2 + b - C_1)(k + hC_1 - hC_Y - hC_2)}{4}$$

Theorem 1: From the above content is easy to get $\pi^{I*} - \pi^{II*} > 0$, that is $\pi^{I*} > \pi^{II*}$.So, centralized decision model for cloud-CLSC can get more total profits than decentralized decision model of cloud-CLSC.

3.4.2The comparison of optimal price between model I and model II

If p^I minus p^{II}, pr^I minus pr^{II},we can get,

$$p^I - p^{II} = \frac{-A + BC_1 + BC_S + 2BC_Y}{4B}$$

$$pr^I - pr^{II} = \frac{hC_1 + k - hC_2 - hC_Y}{4h}$$

Theorem 2: Assume that $p^I < p^{II}$,we can get $-A + BC_1 + BC_S + 2BC_Y < 0$,that is $0 < C_Y < \dfrac{A - BC_1 - BC_S}{2B}$.So, when the price of cloud service is $0 < C_Y < \dfrac{A - BC_1 - BC_S}{2B}$,

retailer selling price in centralized decision model of cloud-CLSC is much lower than decentralized decision model of cloud-CLSC. It can attract more customers, improve product demand, stimulate profit growth by manufacturer enterprise cluster, retailer enterprise cluster and supplier enterprise cluster, consumers can also get preferential price from optimized system of the closed-loop supply chain.

Theorem 3: Assume that $pr^{I} - pr^{II} > 0$, we can get $0 < C_Y < \frac{k - hC_2 + hC_1}{h}$.We find that recycling price by the third party recycling enterprise cluster in centralized decision model of cloud-CLSC is higher than decentralized decision model of cloud-CLSC.

3.5 Optimization of decentralized decision model of cloud-CLSC

From theorem 2, centralized decision model of cloud-CLSC can get more profits than decentralized decision model of cloud-CLSC. But in real life, centralized decision model of cloud-CLSC is an ideal situation, more often we face decentralized decision model of cloud-CLSC. So we need to design the pricing mechanism, to determine the wholesale price or transfer price, making profits of decentralized decision model of cloud-CLSC to tend to or equal to centralized decision model of cloud-CLSC. Based on the assumption of the model III, we will further analyze decentralized decision model of cloud-CLSC.

Profit functions of each member in cloud-CLSC are as follows:

$$\pi_M^{III} = (w - C_Y)Q - (C_2 + b)G - C_1(G - Q)$$

$$\pi_S^{III} = (p - w - C_S - C_Y)Q$$

$$\pi_R^{III} = (b - pr - C_Y)G$$

$$\begin{aligned}\pi^{III} &= \pi_M^{III} + \pi_S^{III} + \pi_R^{III} \\ &= (p - C_1 - C_S - 2C_Y)Q + (C_1 - pr - C_2 - C_Y)G\end{aligned}$$

Assuming that sales price and recycling price in centralized decision model of cloud-CLSC is equal to which in decentralized decision model of cloud-CLSC, we can get formulas of transfer price.

$$\begin{cases} p^{III} = p^{I} = \dfrac{A + BC_1 + BC_S + 2BC_Y}{2B} \\ pr^{III} = pr^{I} = \dfrac{hC_1 - k - hC_2 - hC_Y}{2h} \end{cases}$$

The same as model II, if $\frac{\partial \pi_S{}^{III}(p)}{\partial p} = 0$, $\frac{\partial \pi_R{}^{III}(pr)}{\partial pr} = 0$, we can get,

$$\begin{cases} p = \dfrac{A + (w + C_S + C_Y)B}{2B} \\ pr = \dfrac{bh - k - hC_Y}{2h} \end{cases}$$

By $p^{III} = p, p^{III} = pr$, we have

$$\begin{cases} w = C_1 + C_Y \\ b = C_1 - C_2 \end{cases}$$

We put w , b , p^{III} , pr^{III} into profit function expression of each member in cloud-CLSC, we can get the maximum profit of each node in cloud-CLSC and maximum total profit of cloud-CLSC is $\pi_M{}^{\text{III}*}$ $\pi_S{}^{\text{III}*}$ $\pi_R{}^{\text{III}*}$ $\pi^{\text{III}*}$.

$$\pi_M{}^{\text{III}*} = C_1(A - BC_1 - BC_S - 2BC_Y) - C_1(k + hC_1 - hC_Y - hC_2)$$

$$\pi_S{}^{\text{III}*} = \frac{(A - BC_1 - BC_S - 2BC_Y)^2}{4B}$$

$$\pi_R{}^{\text{III}*} = \frac{(C_1h - C_2h + k - C_Yh)^2}{4h}$$

$$\pi^{\text{II}*} = \frac{(A - BC_1 - BC_S - 2BC_Y)(A - 3BC_1 - BC_S - 2BC_Y)}{4B} + \frac{(C_1h - C_2h + k - C_Yh)(k - 3C_1h - C_2h - C_Yh)}{4h}$$

If π^{I*} minus π^{III*}, we can get

$$\pi^{\text{I}*} - \pi^{\text{III}*} = C_1(C_1h - C_2h + k - C_Yh) - C_1(A - BC_1 - BC_S - 2BC_Y) < 0$$

Theorem 4: From the equation above, we can easily get $\pi^{I*} - \pi^{\text{III}*} < 0$, that is $\pi^{I*} < \pi^{\text{III}*}$. So, through optimizing the model, total profit of decentralized decision model of cloud-CLSC increased is more than centralized decision model of cloud-CLSC.

4. Numerical simulation analysis of the model

Whether the theorem of basic assumptions of the model is effective, we will verify it by numerical simulating analysis and comparison. We assume that manufacturer enterprise cluster and supplier enterprise cluster in cloud CLSC set price decisions based on the accurate market demand. We also suppose the total market size to be 400. At last, we will get comparison of overall profits from the three models. Model parameters are shown in Table 2.

Table 2. Model parameters

parameter	A	B	h	k	C_1	C_2	C_S
data	400	2	10	30	40	20	20

Take the data in Table 2 into model I, model II and model III. We can get data in Table 3 and Table 4.

Table 3. Model I: Cloud service fee and profit of centralized decision model

C_Y	p_1^I	pr^I	Q	G	π^I
0	130.0000	8.5000	140.0000	115.0000	11122.5000
1	131.0000	8.0000	138.0000	110.0000	10732.0000
2	132.0000	7.5000	136.0000	105.0000	10350.5000
3	133.0000	7.0000	134.0000	100.0000	9978.0000
4	134.0000	6.5000	132.0000	95.0000	9614.5000
5	135.0000	6.0000	130.0000	90.0000	9260.0000
6	136.0000	5.5000	128.0000	85.0000	8914.5000
7	137.0000	5.0000	126.0000	80.0000	8578.0000
8	138.0000	4.5000	124.0000	75.0000	8250.5000
9	139.0000	4.0000	122.0000	70.0000	7932.0000
10	140.0000	3.5000	120.0000	65.0000	7622.5000
11	141.0000	3.0000	118.0000	60.0000	7322.0000
12	142.0000	2.5000	116.0000	55.0000	7030.5000
13	143.0000	2.0000	114.0000	50.0000	6748.0000
14	144.0000	1.5000	112.0000	45.0000	6474.5000
15	145.0000	1.0000	110.0000	40.0000	6210.0000

Table 4. Model II: Cloud service fee and profit of decentralized decision model

C_Y	p_1^{II}	pr^{II}	Q	G	π^{II}
0	165.0000	2.7500	70.0000	57.5000	8341.8750

1	165.5000	2.5000	69.0000	55.0000	8049.0000
2	166.0000	2.2500	68.0000	52.5000	7762.8750
3	166.5000	2.0000	67.0000	50.0000	7483.5000
4	167.0000	1.7500	66.0000	47.5000	7210.8750
5	167.5000	1.5000	65.0000	45.0000	6945.0000
6	168.0000	1.2500	64.0000	42.5000	6685.8750
7	168.5000	1.0000	63.0000	40.0000	6433.5000
8	169.0000	0.7500	62.0000	37.5000	6187.8750
9	169.5000	0.5000	61.0000	35.0000	5949.0000
10	170.0000	0.2500	60.0000	32.5000	5716.8750
11	170.5000	0.0000	59.0000	30.0000	5491.5000
12	171.0000	0.0000	58.0000	30.0000	5286.0000
13	171.5000	0.0000	57.0000	30.0000	5083.5000
14	172.0000	0.0000	56.0000	30.0000	4884.0000
15	172.5000	0.0000	55.0000	30.0000	4687.5000

Table 5. Model III: Cloud service fee and profit of decentralized decision model

C_Y	p_1^{II}	pr^{II}	Q	G	π^{II}
0	130.0000	8.5000	140.0000	115.0000	13410.0000
1	131.0000	8.0000	138.0000	110.0000	13280.0000
2	132.0000	7.5000	136.0000	105.0000	13156.0000
3	133.0000	7.0000	134.0000	100.0000	13038.0000
4	134.0000	6.5000	132.0000	95.0000	12926.0000
5	135.0000	6.0000	130.0000	90.0000	12820.0000
6	136.0000	5.5000	128.0000	85.0000	12720.0000
7	137.0000	5.0000	126.0000	80.0000	12626.0000
8	138.0000	4.5000	124.0000	75.0000	12538.0000
9	139.0000	4.0000	122.0000	70.0000	12456.0000
10	140.0000	3.5000	120.0000	65.0000	12380.0000

11	141.0000	3.0000	118.0000	60.0000	12310.0000
12	142.0000	2.5000	116.0000	55.0000	12246.0000
13	143.0000	2.0000	114.0000	50.0000	12188.0000
14	144.0000	1.5000	112.0000	45.0000	12136.0000
15	145.0000	1.0000	110.0000	40.0000	12090.0000

Table 3 and Table 4 tell us that the total profit of the centralized decision model of cloud-CLSC is always higher than that of the decentralized decision model of cloud-CLSC, theorem 1 is proven. Table 3 and table 5 reveal that the total profit of the centralized decision model of cloud-CLSC is always lower than that of the optimization of decentralized decision model of cloud-CLSC, theorem 4 is proven.

5. Discussion

Combining cloud computing technology with closed-loop supply chain, this paper exploits new fields of closed-loop supply chain research. Unlike previous literatures which focus on pricing research of a single closed-loop supply chain, the paper discusses pricing mechanism of cloud closed-loop supply chain. Stackelberg master-slave game model and optimization theory are applied to discuss and compare the synergistic pricing strategy between the centralized and the decentralized decision models of cloud-CLSC, during which the optimal pricing strategy of the enterprise clusters in the corresponding nodes of cloud-CLSC is identified, and the profits gained in each node, as well as the aggregate profits are evaluated. The study also found that enterprises in cloud-CLSC have feature of enterprise clusters and information integration, they are able to make quick response to market changes. From discussions above, some valuable conclusions are drawn, which provide a theoretical reference for the cloud-CLSC development in the future.

6. Conclusions

Closed-loop supply chain is a system which is made up of different economic agents of different strength, each economic agent in closed-loop supply chain may present a conflict of interest, forming different system structure by different dominant force in closed-loop supply chain [10]. So, traditional closed-loop supply chain has widespread problem of information asymmetry or information delayed. These problems will influence the demand forecast and its pricing decision among supply chain members. Closed-loop supply chain needs powerful information technology [11], good organizational structure and good trade partnership to meet synergistic effect. Cloud computing technology uses a large amount of computing resources through network connection to unify management and scheduling. Resources in the "cloud" seems to be extended unlimitedly, users can get resources at any time, use resources on demand and be in a pay-as-you-go model. It would be easier to optimize the closed-loop supply chain by cloud computing. It is possible for each node enterprise cluster of cloud-CLSC to form strategic partners of information resources in highly shared, revenue sharing and risk-sharing.

Acknowledgments

This project is supported by National Social Science Foundation of China (Grant No. 14AGL003), Soft Science Project of Fujian Natural Science Foundation (no. 2016R0074), and JK Project of Fujian Education Department Funds(2015JK026).

References

1. Gong Y. D., Da Q. L.; Research on combinations of closed-loop supply chain dominant mode and logistics mode, 2012; Journal of Management Sciences in China, vol.18, no. 10, pp.14-25.
2. Ma W.M., Zhao Z.; Different models of closed-loop supply chain with the government replacement-subsidy, 2012; Systems Engineering-Theory & Practice, no. 9, pp.1938-1944.
3. Yao W. X., Chen M. M.; Research on the comparison of channel model of closed-loop supply chain, 2010; Commercial Research, China, no. 1, pp.51-54.
4. Wu Y., Cegielski C. G., Hazen B. T., et al.; Cloud computing in support of supply chain information system infrastructure: understanding when to go to the cloud, 2013; Journal of Supply Chain Management, vol.49, no. 3, pp.25-41.
5. Choudhary A., Rana S., Matahai K. J.; A Critical Analysis of Energy Efficient Virtual Machine Placement Techniques and its Optimization in a Cloud Computing Environment,2016; Procedia Computer Science, no.78, pp. 132-138.
6. Chang V., Walters R. J., Wills G. B.; Organisational sustainability modelling—An emerging service and analytics model for evaluating Cloud Computing adoption with two case studies. 2016; International Journal of Information Management, vol.36, no. 1, pp. 167-179.
7. Tang Y., Li J., Zhang J. H.; Cloud manufacturing service platform design of closed-loop supply

chain oriented to remanufacturing, 2012; Computer Integrated Manufacturing Systems, vol.18, no. 7,pp.1554-1562.

8. Hsu P. F., Ray S., Li-Hsieh Y. Y.; Examining cloud computing adoption intention, pricing mechanism, and deployment model, 2014; International Journal of Information Management, vol.34, no. 04, pp.474-488.
9. Talaei M., Moghaddam B. F.; Pishvaee M. S., et al.; A robust fuzzy optimization model for carbon-efficient closed-loop supply chain network design problem: a numerical illustration in electronics industry. 2016; Journal of Cleaner Production, no.113, pp.662-673.
10. Govindan, K., Soleimani, H., Kannan, D.; Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. 2015; European Journal of Operational Research, vol.240, no. 3, pp.603-626.
11. Miemczyk J., Howard M., Johnsen T. E.; Dynamic development and execution of closed-loop supply chains: a natural resource-based view. 2016; Supply Chain Management: An International Journal, Vol. 21, no 4, pp.453 – 469.