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Prices Contract Model and Information Sharing Platform of Closed-loop Supply Chain Based on Recyclers' Competition

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Abstract: Closed-loop supply chain has important economic and social benefits. And recyclers' competition is the characteristic that can't be neglected in many closed-loop supply chains. Based on the assumption of independent between the remanufacturing and new product market, this study had constructed a price contract model of closed-loop supply chain based on recyclers' competition and taken a numerical analysis according to the actual data after adjustment of an enterprise. This study had drawn a result that the cost of recyclers has great effect for closed-loop supply chain coordination in a long time. Finally, in the case of the construction machinery industry, this study had discussed the problem of closed-loop supply chain information sharing platform construction in order to reduce cost and control of the whole closed-loop supply chain for the core enterprise.

Key words: Closed-loop supply chain, recyclers' competition, prices contract, information sharing platform, coordination

INTRODUCTION

Closed-loop supply chain including the forward and reverse supply chain can reuse the EOL (End-of-Life) product that was obsoleted in an open-loop. Through closed-loop supply chain, a lot of value contained in EOL products can be reused in the new life cycle and much energy consumption and environmental pollution can be reduced by the EOL product. Therefore, closed-loop supply chain management is of crucial importance in promoting the development of low-carbon and environment-friendly economy, especially in the background of increasingly conspicuous contradiction between global economic development and environmental pressure. This is particularly evident in developing countries such as China. Currently, the practice of closed loop supply chain practice in China is still at the initial stage and facing the certain gap between theoretical hypothesis and enterprise practice, which results in much difficulty to give the enterprise some theoretical support about closed-loop supply chain management practice.

The instability of material supply is a major disturbance factor of remanufacture that is core of value regeneration in closed-loop supply chain. Therefore, coordination of recycling link would be one of the most critical bottlenecks in closed-loop supply chain coordination between the participating parties. In order to improve the quantity of recycling, remanufacture often tends to face more recyclers which have competition between each other. The rules between recyclers' competition is a clear distinction to current researching single recovery assumes. From the perspective of the core enterprise or government, how to design contract and use information technology to influence and control recycling link in order to improve the recycling product quantity, which become one of the important research direction of the closed-loop supply chain management practices.

LITERATURE REVIEW

As one of hot research theory in recent years, the closed-loop supply chain coordination mainly discusses how design contract to change motivation of different parties in order to reduce or avoid the loss of profits. There are many types of the contract used in the study, but the price contract coordination is the most typical contract that is divided into two kinds: symmetric information and asymmetric information.

Price coordination is mainly to study the supply chain transfer price and revenue sharing between upstream and downstream that has very complex specific type. Research in this fields such as Gu Qiaolun studied on the pricing strategies by game theory (Gu *et al*., 2005); Debo studied remanufacturing cost from a technical and

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market segmentation perspective (Debo *et al*., 2005); Mukhopadhyay and Setoputro discussed the optimal price and optimal return price problem from the perspective of income and cost (Mukhopadhyay and Setoputro, 2004); Ge Jingyan had designed a revenue sharing contract to coordinate a closed-loop supply chain under decentralized decision (Ge *et al*., 2007); Guo Yajun etc., had studied two-order closed-loop supply chain node enterprise decision and had proposed cost sharing contract for closed-loop supply chain coordination based on the analysis of traditional revenue sharing contract and stochastic market demand (Guo *et al*., 2007).

Some studiers had discussed the decision making of various participants from the perspective of closed loop supply chain structure, such as Amaro, etc. had drawn optimal policy under the different parties' cooperation relationship by mixed linear programming method (Amaro and Barbosa-Povoa, 2009); Qiu Ruozhen etc. had discussed pricing decision model of two kinds of recycling mechanisms: Manufacturers recycling and retailer recycling by coordination mechanisms of "two charges system" based on the assumption of market demand stochastic(Qiu and Huang, 2007); Jing Chen, Peter C. Bell had studied decentralized decision coordination of product buy-back closed-loop supply chain composed of a manufacturer and a retailer (Chen and Bell, 2011).

The above research have assumed that each link of the closed-loop supply chain should have one participant and don't discuss competition of recycling link. In the fact of closed-loop supply chain practice, recyclers' competition is many important features. Therefore, this study had studied on prices contract of closed-loop supply chain based on recyclers' competition

The topic has an important significance for advancing the closed-loop supply chain theory, but the basic assume that participants for a closed-loop supply chain each link, the lack of recovery is the competition of discussion. In China's current practice of closed-loop supply chain, more recycling business competition is to make a lot of enterprises have to face one of the important characteristics.

PRICES CONTRACT MODEL OF CLOSED-LOOP SUPPLY CHAIN BASED ON RECYCLERS' COMPETITION

This study assumes that the markets of new products and remanufacturing products are relatively independent, which means consumers of new products generally do not buy the remanufacturing products and consumers of remanufacturing products would not buy the new product. So, the core enterprise of the closed-loop supply chain doesn't consider the impact of the remanufacturing products to the new products market and only considers how the reverse supply chain profit maximized. Remanufacturing products with independent market are widespread in many industries, such as: high-end household appliances, automobile and so on.

Basic assumptions: The basic assumptions of the model are as follows:

- The markets of remanufacturing products and new products are independent of each other
- The closed-loop supply chain is constituted by a core remanufacturer and two competing recyclers. When the core manufacturers make recycling price decision, the rule is the whole profit maximization
- The core remanufacturer provides recycling prices is p_{rm} and the remanufacture costs is c
- Two recyclers' recycling prices are p_{r1} and p_{r2}. The recycling quantity is proportional to the own price and inversely proportional to competitor's price. The recycling quantity obeys the following:

$$Q_{Ri} = r+sp_{ri}-tp_{rj},\ (i = 1, 2\ j = 3-i)$$

Consumers is more sensitive to retailers price changes than rival price changes, so it is s-t>0.

Closed-loop supply chain price contract model with the recyclers decentralized decision: There are two kinds of decision type: Decentralized decision and centralized decision of the two recyclers.

Two recyclers' profits respectively are:

$$\pi_i = (p_{rm}-p_{ri}-c_i)(r+sp_{ri}-tp_{r3-i}\ i = 1, 2$$

So, the optimal recycling price of two recyclers is:

$$\begin{cases} p_{r1}^{*} = \dfrac{sp_{rm}-r}{2s-t} - \dfrac{s(c_2 t+2sc_1)}{4s^2-t^2} \\ p_{r2}^{*} = \dfrac{sp_{rm}-r}{2s-t} - \dfrac{1}{2}c_2 - \dfrac{t(c_2 t+2sc_1)}{2(4s^2-t^2)} \end{cases}$$

Therefore, the total profit of reverse supply chain is:

$$\begin{aligned} \pi_{total} = {} & (p_o - p_{r1} - c - c_1)(r + sp_{r1} - tp_{r2}) \\ & + (p_o - p_{r2} - c - c_2)(r + sp_{r2} - tp_{r1}) \end{aligned} \quad (1)$$

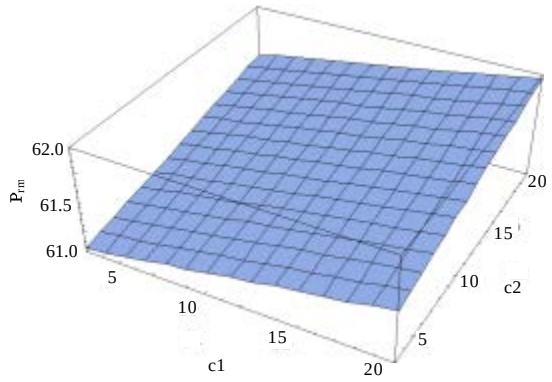

Fig. 1: Relation of recyclers' recycling cost and remanufacture's recycling price

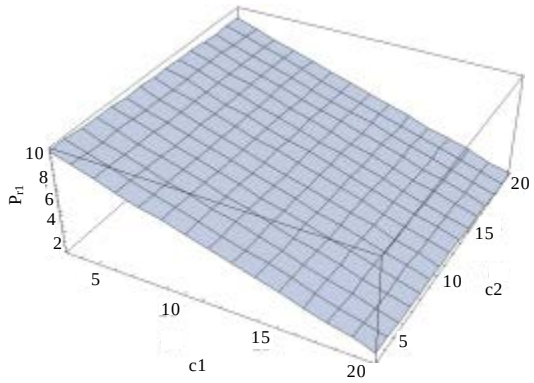

Fig. 2: Relation of recycler R1's price and recycling cost

So, we have:

$$\frac{\partial^2 \pi_{total}}{\partial p_{rm}^2} = -\frac{4s^2(s-t)}{(2s-t)^2} < 0$$

(1) is a concave function in the feasible region. p_{rm} has the optimal value to make (1) attain its maximum under decentralized decision of price contract.

Obviously, the optimal value of p_{rm} is:

$$p_{rm}^* = \frac{1}{4s(s-t)}\{[(c_1+c_2)(s-t)-2r]t + 2(2s^2-3st+t^2)(p_0-c)\}$$

Based on the practice of closed-loop supply chain management of an enterprise, we assume that r = 100, s = 15, t = 3, c_1 = 18, c_2 = 15, c = 30, p_0 = 98. The calculation result shows p^*_{rm} = 62.0167.

In order to explore the relation between competitive retailers in closed-loop supply chain, this study uses Mathematic software to analysis the influence of recycling cost. Relation of recyclers recycling cost and recycling products price of the core enterprise as shown below in Fig. 1.

It can be seen from the above figure, the recycling price of core enterprise is impacted very obvious by recyclers' cost. The processing cost is higher and the recycling price of core enterprise is higher.

The opposite of correlation between remanufacturer recycling price and recyclers' cost, relationship between a recycler price and two recyclers' cost are shown below in Fig. 2.

EOL product recycling prices affected significantly by the recyclers' cost, especially for inferior recycler's cost.

So, there is an important measure for the closed-loop supply chain practice that the core enterprise or government encourages enterprises to establish an information sharing platform because of the recycling cost caused by uncertainty and incomplete knowledge has a significant impact on the coordination.

INFORMATION SHARING PLATFORM OF CLOSED-LOOP SUPPLY CHAIN

According to the theory of extending producer responsibility, this study puts forward a closed loop supply chain management information platform based on Internet of things from the perspective of the core enterprise in supply chain. The platform should be used by the core enterprise when it manages closed-loop supply chain of its product. Construction machinery industry as an example, the infrastructure of information sharing platform provided by the core enterprise in supply chain or independent third party which portal is responsible for monitoring the safety and legitimacy of access, to ensure the security of the whole system. When an access is recognized as legitimate, the information platform should input information to PML server or output information form PML server.

When a part is produced, the parts manufacturer should give an EPC coding on the part and store corresponding data in the PML server group. Supply chain subsequent parties would do with above operation that gives a new ECP coding as long as to generate a new part or product, otherwise, they input own operation information to the products/parts in PML server. Obviously, when the final product produced, a lot of closed loop supply chain information is produced by the downstream supply chain. When a product is back into upstream of the supply chain, the closed loop supply chain participant should output all relevant information

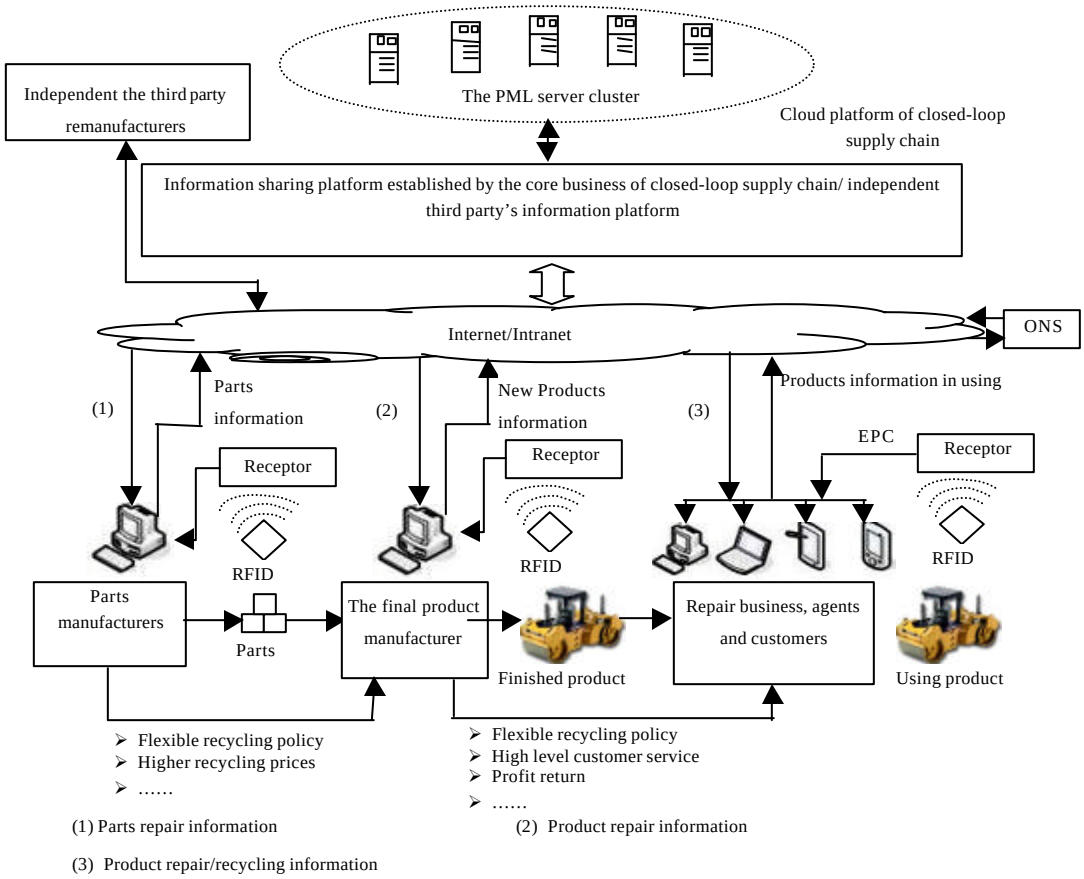

Fig. 3: Information sharing Platform of closed-loop supply chain for construction machinery

from the product beginning of life to the current from PML server which can provide scientific decision support for subsequent reverse logistics processing according to the EPC data. The business process as be shown in Fig. 3.

So, upstream participant need provide some incentive for downstream participants' information collection and input behavior because of benefits and costs are not consistent in closed-loop supply chain upstream and downstream. This kind of incentive can be a flexible recycling policy and also can be a cash return.

CONCLUSIONS

The recyclers' cost is the key factor for the closed-loop supply chain coordination in a long time. Closed-loop supply chain information sharing can effectively reduce the recycling costs, so as to improve the level of closed-loop supply chain long-term coordination. Through information sharing, manufacturers can effectively control the recycling cost of different enterprises and achieve the adjustment purpose of closed-loop supply chain.

The information platform of closed-loop supply chain is the core of the information sharing system. Because of the complexity of the closed-loop supply chain itself, its low cost, high efficiency operation is inseparable from the support of information, so the closed-loop supply chain management model would be based on management information system platform in the future. In order to reduce the resistance of information sharing and mine information platform value, closed-loop supply chain information sharing platform can be constructed by the third party enterprise that should open to every closed-loop supply chain members and even be build as a public third party information service platform for several commonality closed-loop supply chains in someone industry.

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