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Sustainable manufacturing in a closed-loop supply chain considering emission reduction and remanufacturing

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ABSTRACT

This paper aims to explore the decision strategy and profit distribution of a closed-loop supply chain (CLSC) with retail price and emission reduction dependent demand. In the first period, the manufacturer supplies the new products to retailer and the retailer sells the new products to consumers; then the retailer remanufactures the used products and purchased the new products in the second period. Considering the consumer's low-carbon and remanufactured preference, centralized and decentralized models consisting of one-single manufacturer and one-single retailer are proposed to investigate the optimal retail price, reduction rate and recycling rate. Through systematic comparison, the results show that each member makes decisions for self-profits maximization, which inevitably brings about double-marginal effect and affects the operating efficiency of supply chain in decentralized scenario. On the basis of Nash bargaining theory, we use the degree of satisfaction as an objective function and examine the feasibility of coordination mechanism. Finally, a numerical study is taken to investigate the impacts of low-carbon and remanufactured preference on demand as well as optimal decisions.

1. Introduction

During the past few years, resource shortages and environmental pollution have been becoming increasingly acute, more and more the countries and international organizations pay more attention to energy conservation and environmental protection. Sustainable manufacturing plays an important role in saving energy consumption and reducing environment pollution. It is noted that how to effectively realize emission reduction and remanufacturing have become the dominant tendency in a low-carbon and sustainable economy (Mukhopadhyay and Ma, 2009). Carbon reduction in forward logistics and remanufacturing in reverse logistics can be carried out to achieve sustainable manufacturing in a supply chain (Guide and Van, 2009). Some previous studies have shown that, how to effectively realize emission reduction and remanufacturing have become the dominant tendency in a low-carbon and sustainable economy (Mukhopadhyay and Ma, 2009). To carry out carbon emission reduction and remanufacturing management, this can be called by sustainable remanufacturing. During the process of closed-loop supply chain, it's difficult for any firms to achieve desired result if the sustainable remanufacturing has been taken (Webster and Mitra, 2007). Thus, on the one hand, the firms need to undertake responsibilities and obligations of emission reduction, which is beneficial to ease the social environmental problems and create a good corporate image. On the other hand, the utilizing of used products through saving the cost can make the profits be improved. Therefore, the firms in supply chain realize sustainable manufacturing not only by applying emission reduction strategy but also by utilizing remufacturing strategy.

In fact, the consumer's choice of the product affects firms' behaviors, and further affects the profit distribution. Sustainable has become a popular word that permeates daily life. Consumers are increasingly care about the firms' environment responsibility and social responsibility. More and more consumers are considering to purchase environment friendly product. Because there is no difference in the utility and performance of product in related industries, consumers especially who focus more on environment are willing to pay for sustainable products. Obviously, the sustainability can significantly raise the utilization of resources and shows environmental friendliness. Indeed, carbon emission reduction has become an indispensable part of manufacturers' production operations which involve production planning and investment in the forward logistics. Remanufactured products are generally considered to be environment friendly and be lower cost. Meanwhile, considering these changes in the market, firms are redesigning product and process to include features that would appeal to consumers with sustainability preference.

Therefore, the impact of the consumer's preference on the optimal decisions and profits in the closed-loop supply chain under the low-carbon background will be significant. According to sustainable

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manufacturing, this paper is related to the interface between the consumer's preference and supply chain performance, which uses a leader-follower Stackelberg game. The remainder of this paper is organized as follows: Section 2 gives the literature review of the emission-related theoretical and empirical researches. We provide the symbols and assumption of model in Section 3. In Section 4, we formulate the Stackelberg games in different scenarios. Section 5 gives a numerical example and makes sensitivity analysis to show the application of the model. Finally, the conclusions and future research are given in Section 6.

2. Literature review

In this section, we review the literatures focusing on three issues related to the decision and coordination in the closed-loop supply chain. The section firstly illustrates the related literature on the consumer's preference. Secondly, the literature of the multi-period decision in closed-loop supply chain is analyzed. Thirdly, the related literature on the impact of profit distribution on supply chain decisions is reviewed.

2.1. Consumer's preference

Differentiation of consumer's preference on the new and remeanufactured products is significant. Ferguson and Toktay (2006) introduced the collection function to analyze the diverse price strategies of the new manufactured product and remanufactured product with the heterogeneous consumer group. Debo et al. (2006) introduced an oligarchic manufacturer into remanufacturing behavior and analyzed the technology choice based on the remanufactured preference. Atasu et al. (2008) divided the market into common consumer and environmental consumer considering consumers' different willingness to pay for the new and remanufactured products. Then some researchers carried out the study on the decisions of closed-loop supply chain with the consideration of consumer's remanufactured preference. Guide and Li (2010) indicated that the difference of consumers' willingness to pay between the new and remanufactured will have a great impact on the decisions of manufacturer. Abbey et al. (2015) investigated the optimal pricing of new and remanufactured products using a model of consumer preferences based on extensive experimentation. Vishal et al. (2015) studied how consumers perceive the new and remanufactured products, which also revealed that value perceptions of various products affect each other. Shu et al. (2016) formulated a gaming model of the closed-loop supply chain where consumers may or may not be willing to pay remunerative price for remanufactured products. This research is different from the above-mentioned literature in two aspects, we seek to discover optimal decision of carbon emission reduction and develop the two-period decision model in a closed-loop supply chain, which is absent in the existing papers. Moreover, we identify the difference between the new and remanufactured products from the perspective of consumer's preference.

2.2. Closed-loop supply chain

The hot issues in closed-loop supply chain mainly focus on the recycling and remanufacturing of products. Savaskan and Van (2004) found that the joint recycling model has maximum social profits and the model of retailer recycling is superior to the others models about two-echelon supply chain. Bulmus et al. (2013) established the two-period model to decide the production and yield with the capacity constraint and found that the remanufactured cost has the great impact on the decision. Ferrer and Swaminathan (2006) compared the manufacturer's decision under the different models and investigated the reason why the manufacturer would decrease the price is to increase the market sales and the remanufactured products. Webster and Mitra (2007) focused on the competition between the manufacturer and retailer in a two-period game and analyzed the impact of different models on the member's responsibility and decision. Orsdemir et al. (2014) investigated a manufacturer's decisions who faced the competition from a remanufacturer, and found that the manufacturer relies on the quality when it has a stronger position and relies on the quantity when it has a weaker position. Xiong et al. (2013) analyzed the closed-loop supply chain consisting of one-single supplier and one-single manufacturer, which showed that when the cost of new and remanufactured products are quite different, double marginalization will increase and operation performance of system would decrease. Huang and Wang (2017) applied the Stackelberg game to obtain the equilibrium in closed-loop supply chain and analyzed the impact of remanufacturing ability on the performance based on remanufacturing technology lincensing. Chen et al. (2015) presented a two-stage closed-loop supply chain model that considering the uncertainty in the market size, the return volume and the recycle quality. Although the decision models of the close-loop supply chain are developed in the above literature, the consumer's preferences for low carbon and remanufacturing are ignored in previous research.

2.3. Coordination mechanism

Profit distribution amongst members based on the coordination strategy has become the focus in supply chain. Shi and Wu (2009) applied fuzzy decision theory into improving traditional Shapley and introduced the parameter of integrated corrected factor to present the influences of risk and capital appreciation ratio. Saeed and Mohammad (2016) showed that how the amount and price of the internal transactions in each class and the allocated profits depend on the difference between sale and purchase prices in real-time. Wu et al. (2017) analyzed an effective and fair allocation mechanism for the additional profit to promote the consumers' participation in energy distribution based on the method of Game-theory. Dai and Chen (2012) proposed three profit allocation mechanisms which are based on Shapley value, the proportional allocation concept, and the contribution of each carrier in offering and serving requests. Wang et al. (2017) established an integer-programming model that considers transportation cost and vehicle routing cost and improved Shapley value model to distribute the profits. Zhang and Geng (2012) formulated an evolutionary game model of the profit distribution in supply chain and analyzed the influences of the profit distribution on the level of cooperation and average individual income. Chen et al. (2015) researched the coordination mechanism in the supply chain with lead time and price-depended demand, and provided the three-parameter allocation contract to get the complete agreement with the profit distribution of all participants. Li et al. (2009) analyzed profit distribution between the manufacturer and retailer and found that supply chain can realize the perfect coordination with the method of cooperative game Nash bargaining solution. Nagarajan and Soic (2008) used the bargaining model to explore the profit distribution of all the members and put forward the concept of coordinative stability in supply chain. However, they obtain the coordination contract by the traditional cost-sharing or revenue-sharing, while we use a new contract with profit distribution through Nash bargaining.

Drawing on the existing research, this paper provides a basic framework to investigate the CLSC considering the low-carbon and remanufactured preference, and gives insights for better understanding and management. The contribution of our work to the CLSC are summarized in the following. First, in term of the demand construction, we characterize the condition under which the consumers are the low-carbon and remanufactured preference and investigate how the preferences affect the members' decisions and profit in different scenarios. Second, we can obtain the optimal decisions and profit distribution in a two-period closed-loop supply chain.

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