Modelling and Analysis of Some Issues in Sustainable Supply Chain Management

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Abstract

This doctoral study considers environmental, economic, and social goals of a supply chain, and addresses the operational issues successfully. Development and analysis of mathematical models for sustainable closed-loop and reverse supply chain considering waste product collection, waste product quality, inspection, recycling, remanufacturing, CSR, gaming structures, coordination contracts, etc. are the main focus of the study.

The thesis consists of nine chapters. A brief description of supply chain, supply chain management, sustainability and its role in supply chain management, several relevant issues and considerations are given in Chapter 1. In Chapter 2, a brief literature review of sustainable development, corporate social responsibility, game theory in supply chain, and coordination contracts are presented.

In Chapter 3, dual-channel recycling in a closed-loop supply chain (CLSC) which consists of one collector, one recycler, and one manufacturer is considered. In this chapter, Jafari et al.'s (2017) model is extended with a backup supplier considering the uncertainty of the collection of used products. The shortfall quantity of collection is met up by the backup supplier with the estimated fresh raw materials. Under various power structures or interactions of the supply chain entities, different game-theoretic models are developed. It is observed from the numerical study that, depending on the fractional part of the manufacturer's requirements of recyclable wastes supplied by the collector, the performance of the supply chain increases compared to that of Jafari et al.'s (2017) model in the absence of the recycler. However, in the presence of the recycler, the whole supply chain's profit surpasses Jafari et al.'s (2017) profit for any amount of used product collection.

Chapter 4 considers a dual-channel closed-loop supply chain for waste recycling in a similar setting to the previous chapter. However, the customer demand is assumed here to be stochastic. Two different cases of recycling are investigated with centralized, decentralized, and fixed markup game strategies. Optimal results for the two game models are obtained through numerical examples. It is seen that ex-ante pricing commitment *i.e.,* fixed markup strategy is beneficial for the whole supply chain as well as the supply chain entities, compared to the decentralized policy. From the numerical study, it is also observed that when the recyclability degree of wastes increases, the expected total profit increases for the whole supply chain. A higher price sensitivity of customer demand leads to lower profit for the chain members.

Chapter 5 demonstrates a socially responsible closed-loop supply chain for waste recycling. To produce the finished product from wastes, two different cases of recycling is considered - either the manufacturer or the recycler does the recycling. The manufacturer makes effort to increase the demand for the finished product due to its corporate social responsibility (CSR). Centralized and manufacturer-Stackelberg game models are developed in each case and, for economic benefits, a joint revenue and cost-sharing contract is implemented. Optimal decisions are obtained analytically and also through a numerical example. It is seen that though the

manufacturer bears an extra cost to put effort into increasing the demand, the supply chain members can reach a win-win situation through a suitable revenue and cost-sharing contract. It is further observed that recycling by the recycler is beneficial to the supply chain in comparison to the recycling done by the manufacturer itself.

In Chapter 6, a closed-loop supply chain consisting of a manufacturer, two suppliers and two competitive retailers is explored. One retailer sells manufactured products whereas the other retailer sells remanufactured products and takes up corporate social responsibility. One supplier supplies used products or cores for remanufacturing while the other supplier supplies fresh raw materials for manufacturing new products. The manufacturer sells both new and remanufactured products with different wholesale prices. The chapter analyzes the two competitive retailers' different game strategies when the manufacturer acts as the Stackelberg leader. It is shown that remanufacturing is a good policy to adopt for the whole supply chain, not only for economical benefits but also for environmental sustainability. Optimal decisions of the proposed closed-loop supply chain and its members are also supported by a numerical example.

Chapter 7 studies a three-echelon closed-loop supply chain under sustainability consideration through remanufacturing of waste materials. Depending upon the quality, the collector collects the used products and forwards them to the manufacturer for remanufacturing. The collector offers a reward or incentive to consumers to influence them to return the used items. The shortfall amount of collected used items, if any, is met up by the supplier by supplying fresh raw materials. In three separate cases viz centralized, decentralized, and revenue-sharing contract, optimal incentives for end-customers and optimal profits of supply chain members are determined. The revenue-sharing contract is implemented in two different settings - one including the supplier and the other one excluding the supplier. The win-win outcome for the supply chain members is investigated and a specific range of the sharing parameter for the win-win outcome is obtained.

Chapter 8 investigates the impact of greening and promotional effort-dependent stochastic market demand on the remanufacturer's and the collector's profits when the quality of used products for remanufacturing is uncertain in a reverse supply chain. The proposed model is developed to determine optimal profits of the collector, the remanufacturer, and the whole supply chain. Both the centralized and the decentralized scenarios are considered. To motivate the collector through profit enhancement, the remanufacturer designs a cost-sharing contract. Through numerical examples and sensitivity analysis, the impacts of greenness and promotional effort on optimal profits are investigated. The results show that the remanufacturer gets benefited from greening and promotional effort enhancement. However, a higher value of minimum acceptable quality level decreases the profits of the remanufacturer and the collector. A cost-sharing contract coordinates the supply chain and improves the remanufacturer's and the collector's profits. Besides green innovation, remanufacturing mitigates the harmful effects of waste in the environment. It is assumed that the quality of used products is uncertain, and customer demand is stochastic, green and promotional effort sensitive. These two types of uncertainty along with green, and promotional effort sensitive customer demand differs the current study from the existing literature.

In Chapter 9, an outline of overall conclusion of the works done in this doctoral study is given and some future research scopes are referred, which will target to explore more insights of sustainable supply chains.

Sushil Kumar Dey
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11.02.2022
Professor
Department of Mathematics
Jadavpur University
Kolkata-700032