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# Optimal Channel Configuration for Implementing Remanufacturing Business in a Closed-Loop Supply Chain

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## ABSTRACT

This study aims to analyze the optimal channel configuration of a manufacturer in a closed-loop supply chain (CLSC) where the manufacturer is responsible to collect used products and has a competitive dual-channel in selling new and remanufactured products respectively, including through a retailer and a third-party (Model 3PR) or by itself directly and a third-party (Model 3PM) or through a retailer and by itself directly (Model MR). Considering the manufacturer-Stackelberg, it concluded that model MR is the optimal channel configuration in terms of the sales quantity of remanufactured products and model 3PR never be the optimal one. In terms of the overall sales quantity, the profit of the manufacturer and the whole CLSC, whether model 3PM or model MR is the optimal channel configuration depends on the value of the discount perception for remanufactured products, the cost saving of producing remanufactured products, and whether considering the collection process or not.

### KEYWORDS

CLSC, Collection Cost, Competition, Dual-Channel, Environmental Benefit, Game-Theoretic Approach, Manufacturer-Stackelberg, Optimal Channel Configuration, Remanufacturing

## INTRODUCTION

E-waste is one of the fastest growing waste streams worldwide and the amount of e-waste is estimated to reach 52 million tonnes annually by 2021 (Baidya et al., 2019). Remanufacturing, as the proper approach, is one current emphasis on end-of-life management of e-waste. Remanufacturing business can benefit the environment by keeping used products out of the waste stream longer and contribute to social benefit by providing less-advantaged people in the local community with the opportunity to acquire products to increase their standard of living (Jung & Hwang, 2011). Moreover, remanufactured products can capture the demand from different markets which can lead to expanded economic benefit (Ferrer, 1997). Owing to these, many manufacturers have increasingly integrated remanufacturing as one important part of their business and paid much attention to remanufactured products.

Proper and appropriate supply chain, including channel structure and infrastructure location, is crucial for the successes of the concrete business (Majumder & Groenevelt, 2001; Lotfi et al., 2017; Wang & Mishima, 2019). In terms of the remanufactured products, the appropriate channel structure is vital mostly because that the sale of remanufactured products may cannibalize the sale of new products (Majumder & Groenevelt, 2001). It has been noted that manufacturers may establish

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its own direct channel to sell either new products or remanufactured products, but not both to avoid the cannibalization (He et al., 2019a). In order to investigate channel structure selection and pricing decisions of a manufacturer who sells competing new and remanufactured products, three dual-channel models were developed by He et al. (2019a). They investigated how the subsidy of government promote the adoption of three different dual-channel structures for the manufacturer. However, the collection process is excluded from their study. Remanufacturing operations involve collecting used products, bringing them back to as-new condition, and selling them again (Örsdemir et al., 2014; Atasu et al., 2010). To fill this gap, this study is undertaken to explore the optimal channel configuration decision-making for implementing remanufacturing business in a dual sale channel closed-loop supply chain (CLSC) where the collection process is incorporated.

In this study, a CLSC comprised of a manufacturer (M), a retailer (R) and/or a third-party retailer (3P) is considered. The manufacturer is responsible for the collection of used products. Three dual sale channel configurations are considered. They are: 1) the manufacturer sells new products through the retailer and sells remanufactured products through the third-party retailer (Model 3PR); 2) the manufacturer sells new products by itself directly and sells remanufactured products through the third-party retailer (Model 3PM); 3) the manufacturer sells new products through the retailer and sells remanufactured products by itself directly (Model MR). Based on the equilibrium results and a numerical study, this paper analyzes the influence of several parameters including consumers' perception between new and remanufactured products on the selection of the optimal channel configuration, where the channel configurations' performances are valued by the manufacturer's profit, the sales quantity of remanufactured products, the overall sales quantity and the total profit of the whole CLSC. Then the optimal channel configuration for implementing remanufacturing business is decided accordingly. Moreover, the importance of the collection process in deciding the optimal channel configuration for implementing a remanufacturing business is emphasized.

The remainder of the paper is organized as follows. Section 2 provides three main research streams as literature review. Section 3 presents the model assumptions and notations, while the equilibrium solutions are given in section 4. Then this paper explores the influence of several parameters on the equilibrium results through a numerical study and provides four indicators to compare the performance of the three channel configurations in section 5. Finally, section 6 summarizes the main conclusions.

## LITERATURE REVIEW

In the related literature, we mainly list the related studies involving remanufacturing process or remanufactured products (Table 1). There are three main streams: CLSC management, channel comparison and competition, and competition between new and remanufactured products.

CLSC consists of both a forward supply chain and a reverse supply chain (Huang et al., 2013; Mehrjerdi & Lotfi, 2019). Focusing on remanufactured products, Choi et al. (2013) investigated a CLSC which consists of a retailer, a collector, and a manufacturer, and examined the performance of different CLSC under different channel leadership, namely the collector-leadership, manufacturer-leadership and retailer-leadership. By introducing the demand function of "retail price and product quality dependent demand" and "the price and effort dependent demand", Maiti and Giri (2015) and Gao et al. (2016) respectively explored the influence of different channel power structures on the optimal decisions and performance of a CLSC. The focal points of these studies are to explore the influence of channel leadership in the CLSC and try to optimize the CLSC by introducing different mechanisms or contracts. Channel comparison however is out of consideration.

To investigate the performance of different channels in CLSC, Savaskan et al. (2004) firstly modelled three independent CLSC by changing the collection party (collection undertaken by manufacturer or retailer or third-party) and compared the optimum results of each channel structure. By dynamic modelling method, Giovanni and Zaccour (2014) extended the above models to two-period models to study a remanufacturer appropriates of the returns' residual value and to decide

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