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Don't forget your supplier when remanufacturing

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ABSTRACT

A popular assumption in the current literature on remanufacturing is that the whole new product is produced by an integrated manufacturer, which is inconsistent with most industries. In this paper, we model a decentralised closed-loop supply chain consisting of a key component supplier and a non-integrated manufacturer, and demonstrate that the interaction between these players significantly impacts the economic and environmental implications of remanufacturing. In our model, the non-integrated manufacturer can purchase new components from the supplier to produce new products, and remanufacture used components to produce remanufactured products. Thus, the non-integrated manufacturer is not only a buyer but also a rival to the supplier. In a steady state period, we analyse the performances of an integrated manufacturer and the decentralised supply chain. We find that, although the integrated manufacturer always benefits from remanufacturing, the remanufacturing opportunity may constitute a lose–lose situation to the supplier and the non-integrated manufacturer, making their profits be lower than in an identical supply chain without remanufacturing. In addition, the non-integrated manufacturer may be worse off with a lower remanufacturing cost or a larger return rate of used products due to the interaction with the supplier. We further demonstrate that the government-subsidised remanufacturing in the non-integrated (integrated) manufacturer is detrimental (beneficial) to the environment.

1. Introduction

Remanufacturing is "a production strategy whose goal is to recover the residual value of used products by reusing components that are still functioning well" (Debo et al., 2005). Its economic and environmental implications have gotten a lot of publicity. As a natural low-cost alternative to the traditional manufacturing, remanufacturing can play an important role in increasing profits, as shown by successful examples from many industries (Geyer et al., 2007). In addition, remanufacturing enjoys a green reputation since it reduces the disposal of used products and consumes less natural resources and energy than manufacturing all-new products (Giuntini and Gaudette, 2003). Therefore, environmental groups and governments are increasingly encouraging manufacturers to engage in remanufacturing (Hammond and Beullens, 2007; Ma et al., 2013). For instance, the Chinese Government launched a pilot programme in 2010, providing subsidies to a few selected manufacturers that had no remanufacturing experiences to develop remanufacturing technologies and build reverse logistic networks (China NDRC, 2010).

Nevertheless, most manufacturers do not choose to remanufacture their products. Such a phenomenon is explained mainly from the resource-based view: most manufacturers do not possess the infrastructure and expertise to collect used products and remanufacture them in a profitable manner (Ferguson, 2010). Even if remanufacturing is independently profitable, manufacturers may still ignore this option due to concerns about the cannibalisation of higher-margin new product sales (Atasu et al., 2010; Ferguson and Toktay, 2006). At the same time, the positive environmental profile of remanufacturing is being challenged by latest theoretical findings. Galbreth et al. (2012) shows that remanufacturing can actually increase total virgin material usage because introducing remanufactured products at a low price to the market increases the overall demand. Agrawal et al. (2012b) finds that leasing is not always greener than selling, so encouraging remanufacturing, which raises the value of off-lease product and makes leasing more profitable, may lead to heavier environmental burden.

When modelling the closed-loop supply chain, like most of the literature on remanufacturing, all above mentioned analytic studies assume that the production of the whole new product is done by an integrated manufacturer. But does the interaction on new

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product production make no difference to the performance of closed-loop supply chains with remanufacturing? To answer this question, in this paper, we model and investigate a decentralised closed-loop supply chain consisting of a key component supplier and a non-integrated manufacturer.

This research is motivated by the pilot programme of auto part remanufacturing in China launched by Chinese National Development and Reform Commission (Xinhuanet.com, 2008). Three auto enterprises such as China First Automobile Group are selected and supported by the government to remanufacture auto parts. However, unlike their western or Japanese counterparts, most Chinese auto manufacturers generally have no capacity to design and produce high-quality key components such as automotive engine and gearboxes. They are heavily dependent on key component suppliers. Thus, when these manufacturers engage in remanufacturing, not surprisingly, a great part of the remanufactured product will be initially produced by their suppliers. Intuitively, the remanufactured product will erode the demand for new components. With anticipation of the remanufacturing opportunity, a supplier, especially a key component supplier with the dominant channel power, can respond by strategically adjusting the new component price, which in turn influences the manufacturer's remanufacturing decision. To focus on the impact of the interaction between the key component supplier and the non-integrated manufacturer on the economic and environmental implications of remanufacturing, we consider a simple bilateral monopoly, as depicted in Fig. 1. Here, in accordance with industrial practices (Fleischmann et al., 2003), we specify that the process of remanufacturing is on the level of the component rather than the whole product. The collected used products are disassembled into their constituent components, which are processed, reassembled, tested and made ready for sale as remanufactured products. In such a context, this paper seeks to provide a better understanding on the following research questions:

- If the remanufacturing cost is sufficiently low to overcome the negative impact of cannibalisation on new product sales, should the manufacturer always engage in remanufacturing?
- When engaging in remanufacturing, can the manufacturer be always better off by lowering the remanufacturing cost or enlarging the return rate of used products?
- Are the manufacturer's remanufacturing activities, especially the government-subsidised remanufacturing activities, always beneficial to the environment?

The rest of this paper is organised as follows. Section 2 reviews the literature. Section 3 introduces the assumptions and notations. Sections 4 analyses the performance of an integrated manufacturer as a benchmark. Section 5 analyses the performance of the decentralised closed-loop supply chain. Section 6 examines the environmental implications of remanufacturing. Section 7 concludes this research.

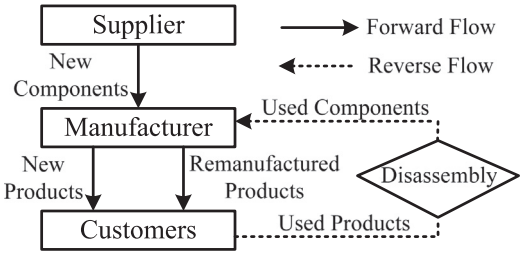

Fig. 1. The decentralised closed-loop supply chain with remanufacturing.

2. Relevant literature

Our work mainly draws on and contributes to the current literature on managing closed-loop supply chains with remanufacturing. For an overview of this research field, we refer the reader to Atasu et al. (2008a) and Guide and Van Wassenhove (2009). Earlier efforts focus on optimal strategies in an integrated system with only one decision-maker. However, closed-loop supply chains generally involve many more independent players than traditional supply chains. Therefore, there has been emerging research interests in either the competitive strategy or the supply chain interaction of multiple decision-makers in the closed-loop context. However, note that these two literature streams typically assume the whole new product is produced by an integrated manufacturer.

The literature on competition in remanufacturing generally employs game theory to model pricing/production quantity decisions for an integrated manufacturer facing competition from independent remanufacturers (Ferrer and Swaminathan, 2006, 2010; Majumder and Groenevelt, 2001). These studies conclude that the entry of independent remanufacturers is detrimental to the manufacturer, and suggest that the manufacturer should remanufacture or collect used products to pre-empt new entrants (Ferguson and Toktay, 2006). Heese et al. (2005) and Atasu et al. (2008b) analyse the profitability of remanufacturing under a direct manufacturer competition. Their results show that remanufacturing can be an effective marketing strategy that allows an integrated manufacturer to defend its market share via price discrimination. Debo et al. (2005) solves joint technology selection and pricing decisions for new and remanufactured products faced by an integrated manufacturer, and extend their model to the case of multiple competing remanufactures. They discover that new and remanufactured products may exhibit the characteristics of complementary products because remanufacturing requires used products as cores.

The impacts of interactions between supply chain partners on the performance of closed-loop supply chains are highlighted by many studies. Ostlin et al. (2008) shows that remanufacturing becomes more effective when there is a clear win–win situation for all players. Savaskan et al. (2004) explores the problem of choosing the appropriate reverse channel structure for collecting used products, Karakayali et al. (2007) and Kaya (2010) analyse decentralised collection and processing operations between a collector and a remanufacturer. In these three papers, two-part tariff contracts are designed to coordinate the channel. Bhattacharya et al. (2006) addresses the problem of determining the optimal order quantity by analysing interactions among a retailer, an integrated manufacturer, and an independent remanufacturer. In their model, new and remanufactured products are perfect substitutes, and the remanufacturer sells remanufactured products through the manufacturer. Thus, the remanufacturer actually acts as a low-cost supplier, though its production capacity is bounded by new product sales.

To the best of our knowledge, there are only two papers involving the supplier when investigating the operational performance of closed-loop supply chains. Aras et al. (2006) considers a hybrid manufacturing/remanufacturing system in which a non-integrated manufacturer purchases new components from the supplier and remanufactures used products. In their model, the manufacturer is the only decision-maker, so the interaction with the supplier is ignored. Jacobs and Subramanian (2012) examine the effects of sharing product recovery responsibility between a supplier and a non-integrated manufacturer. In their model, both virgin material and recycled material are provided by the supplier, so there is no direct competition within the supply chain. In contrast, with the