



Price and service competition between new and remanufactured products in a two-echelon supply chain

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ABSTRACT

In this paper, we consider a supply chain consisting of two manufacturers and a retailer. The first manufacturer is a traditional manufacturer that produces the new product, while the second manufacturer operates a reverse channel producing remanufactured products from used cores. Both manufacturers bundle their products with services, including warranty and advertisement, and they sell through the same retailer, which independently determines the sales prices. We assume that the second manufacturer invests extra effort in facilitating the remanufacturing process. In this study, we identify the equilibrium characteristics with respect to the remanufacturer's effort and price and service decisions for all members of the supply chain. We also investigate the profits of chain members by considering different interactions between prices and service. Based on the theoretical and numerical analyses, we derive economic and managerial insights for chain members.

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1. Introduction

Remanufacturing is the process whereby some components of used products are disassembled, cleaned, reprocessed, inspected, and then reassembled to be used again. Consumer awareness, oversight from non-governmental organizations, and legislative pressures have encouraged manufacturers to produce green and eco-friendly products, and thus, more and more manufacturers now build reverse channels to recycle used products for remanufacturing. However, rather than environmental concerns, the economic benefits that accompany remanufacturing is the main consideration for manufacturers. Because of decrements in the costs associated with raw material production, a remanufacturing system provides an opportunity to reduce not only the environmental burden but also production costs. According to a recent report by [Global Industry Analysts \(2010\)](#), global automotive manufacturing is growing, and by 2015, it is forecasted to reach US\$104.8 billion. Such a strong growth in remanufacturing is also present in other industries, such as toner and inkjet cartridges, electrical equipments, consumer electronics, and furniture ([Hauser and Lund, 2008](#)).

In practice, it is important for manufacturers to adjust their sales strategies in response to the introduction of remanufacturing. For instance, the large personal computer manufacturer, HP Inc., has adopted a remanufacturing program called "HP Renew Program" for recycling and selling the remanufactured or refurbished products. Its remanufacturing program certifies that the remanufactured products

performing well and can substitute new products at lower prices, and it also provides warranty and service for the remanufactured products. Thus far, not all HP's competitors have followed suit, and therefore, the consumers must choose between remanufactured and new products based on product information of prices and service offerings. In the context of this business model, a comparative investigation of price and service for new versus remanufactured products is useful for manufacturers as well as retailers, as it should provide valuable insights into the interactions between price and service, sales decisions, and performance.

To the best of our knowledge, all the previous studies examining remanufacturing are models that only consider the remanufactured product while ignoring the competition, or they are competitive models with a single price attribute. In this study, we incorporate the competitive nature of products and service into our supply chain model of a common retailer and two manufacturers. One manufacturer produces the new product, and the other produces the remanufactured product under the framework of product competition. In our model, we analyze the effects of competition, and thus, we consider four competitive interactions: the presence of price and service competition, price competition only, and service competition only as well as the absence of both price and service competition. Note that the interaction with both price and service competition can be viewed as a general model such that the demand functions, chain members' profit functions, and equilibrium decisions for other interactions can be obtained from this competitive model.

Our analyses reveal that when remanufacturing leads to more cost-savings, the remanufacturer will provide a higher service level to the customers than the traditional manufacturer. Moreover,

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production cost always has negative effects on the chain members' decisions; however, the effects of the costs of recycling and service investment on equilibrium decisions depend on the intensities of price and service competition, especially in determining the new-product manufacturer's equilibrium decisions. Comparing the different interactions, we find that in the presence of competition, the manufacturer has an incentive to remanufacture, yet the opposite is the case in the absence of competition. Moreover, for the retailer, price competition generally enhances profits from the remanufactured product, and thus benefits the remanufacturer. Meanwhile, service competition is profitable for the retailer yet detrimental to both manufacturers. However, the remanufacturer is likely to engage in service competition when cost-savings from remanufacturing are significant or recycling costs are low. Moreover, remanufacturing is an effective strategy in a highly price-sensitive market, even in the absence of price competition.

The remainder of this paper is organized as follows. Section 2 surveys the related literature while emphasizing the contribution of our work. In Section 3, we formalize price- and service-sensitive market demands and chain members' profit functions, and we derive their best response functions. Then, we solve for the member equilibrium decisions under the four competitive interactions. Section 4 presents analytical analyses of chain members' equilibrium decisions with respect to the cost parameters, and then it describes numerical studies that examine the effects of cost- and demand-related parameters on chain members' equilibrium profits. The final section concludes with a brief summary, including suggestions for future research.

2. Literature review

This study relates to two streams of literature: one examines the dynamics of chain members' service decisions in the face of service incentive demand, and the other explores supply chains with remanufacturing. Previous studies in the first stream of literature have concentrated on service interactions in supply chains under game theoretical models (Bernstein and Federgruen, 2007; Cohen and Whang, 1997; De Borger and Van Dender, 2006; Desiraju and Moorthy, 1997; Ray, 2005; Tsay and Agrawal, 2000; Winter, 1993; Xia and Gilbert, 2007; Xiao and Yang, 2008; Zhen, 2012). Cohen and Whang (1997) used a product life cycle model to study the sales prices and service qualities in a supply chain with a manufacturer and a service shop. In this model, the manufacturer sells the product as well as provides the after-sales service, while the service shop only provides service. They adopted a time-dependent utility function to construct market demand, and then sequentially analyzed the price and service decisions of members. Tsay and Agrawal (2000) studied a supply chain with two competing retailers with a common manufacturer in which both the retailers provide products as well as service to customers. Thus, retailers sell the same products and compete along price and service. Xia and Gilbert (2007) focused on a supply chain model with two substitutable products in which the product service levels are provided by a manufacturer, and the prices are determined by a dealer (i.e., a retailer). This setting is applicable to consumer electronics, computer devices and automobiles, which widely adopt remanufacturing. Many models have also addressed service competition, such as Ba et al. (2008), Bernstein and Federgruen (2007), De Borger and Van Dender (2006), Darian et al. (2005), Dan et al. (2012), and Kurata and Nam (2010); however, only forward channels are examined in these studies.

More recently, studies have begun to take into account remanufacturing as a part of production. However, these studies have focused on price interaction within a closed-loop supply

chain in the absence of service interactions, and often analyzed the recycling effort or profitability associated with remanufacturing (Atasu et al., 2008; Debo et al., 2005; Ferrer and Swaminathan, 2006; Guide and Van Wassenhove, 2009; Hsueh, 2011; Liang et al., 2009; Mitra and Webster, 2008; Pokharel and Liang, 2012; Robotis et al., 2005; Robotis et al., in press; Savaskan et al., 2004; Savaskan and Van Wassenhove, 2006; Vadde et al., 2011). Savaskan et al. (2004), for instance, studied price decisions and collection effort in a supply chain with three types of reverse channels for remanufacturing in comparison with a centralized system; the study examined the incentives provided to the customer in order to improve the collection of used items in the absence of the competition. Savaskan and Van Wassenhove (2006) further extended the previous closed-loop supply chain models by considering a duopolistic competition with a retailer; it also discussed the interactions surrounding price decisions with respect to forward and reverse channels. Atasu et al. (2008) examined remanufacturing as a marketing strategy by considering several factors, including cost savings, green-market segment, competition with new products, and product life cycle. The study found that a remanufactured product is more profitable under monopolistic competition, even in the absence of a green market segment. Moreover, the study also pointed out that smart price decision-making is important as the manufacturer cannibalizes used products. A few recent studies including Atasu et al. (2008), Debo et al. (2005), Ferrer and Swaminathan (2006), Majumder and Groenevelt (2001), Mitra and Webster (2008), and Savaskan and Van Wassenhove (2006) have shed light on competition in closed-loop supply chains with remanufacturing, but they all focus exclusively on price competition.

This paper differs from the aforementioned studies in two aspects. First, we assume that manufacturers compete in a duopoly, and second, we incorporate service competition between manufacturers. As discussed in Atasu et al. (2008), remanufactured products usually have lower customer valuations, and thus, manufacturers with remanufacturing (e.g. HP Inc.) may provide service (e.g., product information, after-sales maintenance, etc.) for customers to stimulate sales. Moreover, the remanufactured versus new products possess different characteristics in terms of cost structures and interactive effects such that remanufactured products directly relate to the amount a manufacturer invests in remanufacturing. Thus, a study of the interactions between price and service decisions and an analysis of profitability of these two products should provide useful insights to supply chain members.

3. The model

Consider a supply chain comprised a manufacturer that produces new products from raw materials, a remanufacturer¹ that produces remanufactured products from used items directly collected from customers (Savaskan et al., 2004; Savaskan and Van Wassenhove, 2006), and a common retailer that sells the products of these two manufacturers on the market. The two products are functionally the same. However, the customers treat them differently as new and remanufactured products. The retailer independently determines the sales prices of the two products. Each manufacturer produces only one product, and each has the opportunity to enhance demand by bundling the product with service, such as sales effort (e.g., advertisement, product information) (Tsay and Agrawal, 2000) or

¹ In many instances, we use "remanufacturer" specifically to refer to the manufacturer producing the remanufactured products. In other instances, we refer to both the manufacturer and the remanufacturer as the "two manufacturers." Moreover, we refer to the retailer as female and the manufacturers as males.

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