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Competitive remanufacturing strategy and take-back decision with OEM remanufacturing

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ABSTRACT

Consumer desire for environment-friendly and economical products drives original equipment manufacturers (OEMs) to offer remanufactured products. Thus, OEMs compete with independent remanufacturers (IRs) not only in sales but also in collection of used items for remanufacturing. In this paper, we develop a closed-loop supply that consists with an OEM that sells new and remanufactured products and an IR. Each firm is endowed with two remanufacturing strategies that drive economies of remanufacturing by sales or collection. We then elaborate the relation between the firms' decisions and the remanufacturing strategies, and further derive the equilibrium decisions and strategic schemes. We find that OEM remanufacturing provides the OEM with the variability to respond to changes of competitive scenarios by allocating sales between new and OEM-remanufactured products, compelling the IR to react differently. We further show the conditions for firms to determine their profitable strategies, and characterize the firms' equilibrium strategic choices and operational decisions. This study provides managerial insights for OEM and IR managers in terms of firms' equilibrium behavior.

1. Introduction

The increasing demand for environmentally friendly products encourages independent remanufacturers (IRs) to enter a market and sell remanufactured products, which are made of end-of-life products that were originally produced by original equipment manufacturers (OEMs). The entrance of remanufactured products erodes the sales of new products produced by OEMs. According to a survey conducted by United States International Trade Commission (2012), the value of U.S. remanufactured production grew by 15% to at least $43 billion between 2009 and 2011. Similarly, Global Industry Analysts (2010) announced a report that shows the automotive remanufacturing industry in the world market to be forecasted to reach $104.8 billion by 2015. In the face of such a great threat from remanufactured products, a growing number of OEMs have extended their product lines to offer OEM-remanufactured products – i.e., "OEMs are fast learning to adroitly maximize their profits by offering a judicious mix of both new and remanufactured versions of their product brands," as mentioned by Global Industry Analysts (2010). Moreover, environmental legislation, e.g., EU End-of-Life Vehicle Directive (ELV Directive) and Waste Electrical and Electronic Equipment Directive (WEEE Directive), requires OEMs to establish return channels for consumers to collect end-of-life products, and thus encourage OEMs to engaging in remanufacturing/recovering. WEEE-like legislation has also been introduced in Canada, Japan, China and a number of states in the U.S. (Neto, Walther, Bloemhof, van Nunen, & Spengler, 2010), indicating that the governments promote environmental production by closing the loop between sales, collection, and manufacturing. Another consideration for OEMs to introduce remanufacturing is to deter IRs by strategically collecting used products, thereby decreasing the availability of used products acquired by rival IRs, as discussed by Debo, Toktay, and Van Wassenhove (2005) and Matsumoto and Umeda (2011). These drivers boost OEMs to become main sellers of remanufactured products in the aerospace and motor-vehicle industries in the United States, as reported by the investigation of United States International Trade Commission (2012). For example, Caterpillar Inc. has been engaging in OEM remanufacturing by innovating their business model with sustainable production, and its remanufacturing business grew by 208% in 2011 compared to 2010, as stated by Folley (2012). In Japan, an empirical study of remanufacturing practices conducted by Matsumoto and Umeda (2011) indicated the success of OEM remanufacturing in the industries of photocopiers and single-use cameras.

The collection of used products is the first step in remanufacturing. Many empirical studies (e.g., Matsumoto & Umeda, 2011; United States International Trade Commission, 2012; Walsh,

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Waugh, & Symington, 2015) noted that the availability and collection of used products are the key elements for a successful remanufacturing, inducing OEMs that engage in remanufacturing to interact with IRs not only on sales but also on the collection of used products. Because of the coexistence of sales and collection activities in closed-loop supply chains, firms desire to understand when the economies available through remanufacturing should be driven by sales or collection, as mentioned by Stahel (1995), Fleischmann (2001), and Li and Li (2011). In the sales-driven system, the operational decisions are made to achieve profit maximization, and the remanufacturing supply chain has been widely discussed in previous studies (Atasu, Sarvary, & Van Wassenhove, 2008; Ferrer & Swaminathan, 2006; Ferguson & Toktay, 2006; Li, Li, & Saghafian, 2013). In contrast, when remanufacturing is driven by collection, the operational decisions are made contingent to the collection of used products. An investigation of remanufacturing industries conducted by Walsh et al. (2015) demonstrated that the barrier of collecting sufficient used products leads many remanufacturing businesses to be supply-constrained, indicating the prevalence of collection–driven economics in remanufacturing industries.

However, the previous research considered that the decisions on remanufacturing are either driven by sales or collection, or they assumed that the collection of used products is sufficient for remanufacturing to be exogenously determined by the scales of recycle markets. In practice, sufficient collection of used products is likely to be achieved by firms through incentive/reward mechanisms. For instance, Panasonic Co. provides customers with trade-in rewards for recycling and reusing their used Toughbook mobile computers. In the United States, Hewlett–Packard Co. employs the "Consumer Buyback and Planet Partners Recycling Program," which offers customers rewards such as cash and gift cards for recycling a variety of HP products, and then sells these used products in the secondary market after remanufacturing. Nastu (2009) and Wu (2015) showed that office product retailers, such as Staples, OfficeMax and Office Depot, collect used printer cartridges by providing a reward ranging from $2 to $5 per unit. A few studies (Bulmus, Zhu, & Teunter, 2014; Li et al., 2013; Wu, 2015) analyzed the decisions of take-back rewards, but they overlooked the coexistence of new and OEM-remanufactured products, or neglected the firms' strategic and operational interactions on sales and collection. This study contributes to the literature by examining that the firms provide rewards for returns to endogenously achieve the needs of remanufacturing and investigating the firms' operational and strategic interactions on the pricing and take-back decisions between an IR and an OEM.

In this study, we develop a game-theoretical model to formulate firms' interactions on prices and rewards for returns, and further derive the equilibrium decisions under different schemes of remanufacturing-driven strategies. We seek to determine the circumstances under which firms should choose sales–driven or collection–driven strategies. Subsequently, we characterize the influences of potential cost and market factors on the firms' equilibrium behavior towards operational decision-making and strategic choices to understand how the firms react with each other with respect to the changes of the exogenous factors and the rival strategy.

The remainder of this paper is organized as follows. After reviewing the related studies in Section 2, we present a competitive model consisting of an OEM and an IR in Section 3. We formulate their interactions on sales and collection, derive the market demand and collected quantity for each product from consumer utility functions, and formulate the firms' profit functions. We then derive the firms' equilibrium decisions under the possible strategic schemes. Section 4 analytically identifies the characteristics of the firms' equilibrium results. Section 5 provides computational experiments to help understand the effects of cost-related, market-related, and consumer-valuation factors. The final section concludes the findings of this study and identifies potential future research directions.

2. Relevant literature

Interactions in closed-loop supply chains have received increasing attention in the field of operational management (e.g., Ahiska & Kurtul, 2014; Atasu et al., 2008; Debo et al., 2005; Ferrer & Swaminathan, 2006; Ferrer & Swaminathan, 2010; Ferguson & Toktay, 2006; Guo & Ya, 2015; Hafezalkotob, 2015; Wei & Zhao, 2015; Wu, 2012; Xu, Li, & Cai, 2012; Zhou, Xiong, Li, Xiong, & Beck, 2013). For example, Ferrer and Swaminathan (2006, 2010) discussed competition between new and remanufactured products in monopoly and duopoly environments regarding different planning horizons; moreover, they identified the parametric effects of competition and cost on market segments and on firms' behavior. Atasu et al. (2008) noted the market scenarios in which a monopolist can profitably offer remanufactured products as a marketing strategy; furthermore, they investigated the influence of the presence of a competitor that sells an alternative new product. Zhou et al. (2013) also examined the interaction between new and remanufactured products that are produced by an OEM; however, they concentrated on the OEM's profitability with respect to the centralized and decentralized decision-making models. Interestingly, these researchers determined that the decentralized model may outperform the centralized model under certain conditions. Wei and Zhao (2015) established several game models to investigate the firms' pricing and remanufacturing decisions under the competition between a conventional supply chain and a remanufacturing supply chain. Hafezalkotob (2015) incorporated the issues of government incentives for greening, and investigated the interactions between two competing supply chains under six scenarios composed of different government tendencies and decision-making structures. However, the focuses of the aforementioned studies are mainly on competition between new and remanufactured products in the sales market (forward channel). Thus, firms' interactions and consumer behavior in reverse channels have not been developed, and collected quantities for remanufacturing are assumed to be exogenously given. In this study, we examine that the collected quantity can be controlled by the firms' endogenous incentives in regard of consumer utility from return. Wu (2012) extended the focuses of previous studies by incorporating after-sales service competition and examined the firms' equilibrium decisions and profits with regard to different interactions between prices and service levels. Xu et al. (2012) investigated the production planning of a monopolistic manufacturer that sells both new and remanufactured products in a stochastic environment. Specifically, they derived the optimal acquisition price and quantities by considering the difference in production lead time between two products. Nevertheless, the competition between OEMs and IRs and the entry of OEM-remanufactured products have not been simultaneously considered in the aforementioned studies. This paper aims to fill this gap by examining the interactions between an IR and an OEM that sells both new and remanufactured products.

Another stream of studies examine the issues of the take-back decisions in remanufacturing. Kaya (2010) developed a single-period model to examine take-back incentive and production decisions by a manufacturer that offers both new and remanufactured materials in production. Kaya's study focused on the performance of a monopolistic manufacturer and the effectiveness of coordination contracts and thus overlooked competition with other firms. Jung and Hwang (2011) examined competition and cooperation between an OEM and a remanufacturer that collects end-of-life