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Optimal strategies for trade-old-for-remanufactured programs: Receptivity, durability, and subsidy

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ABSTRACT

Due to its environmental, financial, and marketing benefits, businesses and governments have increasingly embraced remanufacturing. However, the weak demand for remanufactured (reman) product severely hinders the implementation of remanufacturing. Lately, Trade-Old-for-Remanufactured (TOR) programs are growing in popularity as they can boost reman product demand. In this paper, we investigate the conditions when a firm should offer a TOR program and how to best implement it. Our main findings are: (1) Firms should offer TOR programs only when reman product receptivity and new product durability satisfy a certain condition; (2) In addition to the reman product receptivity, the new product durability also plays a significant role in motivating consumers to participate in TOR programs; and finally (3) High product remanufacturability and government subsidies are strong incentives for firms to offer their TOR programs. Our analysis provides insights for firms and governments on how to use TOR programs to benefit businesses, consumers, and the environment.

1. Introduction

Remanufacturing is an industrial process that repairs, replaces, or restores used products to bring them to like-new states (Agrawal et al., 2015). Because of environmental, financial, and marketing benefits, remanufacturing has attracted much attention and interest. Government legislation often requires manufacturers to recycle/remanufacture their used products. For example, Directive 2002/96/EC (EUR-Lex, 2003) sets minimum targets for component, material, and substance reuse and recycling rates at 75% by weight for large household appliances and 65% for computers and printers. Even without legislation, drawn by economic profits, many manufacturers (e.g., Xerox, HP, and EPSON) have proactively remanufactured used products. Vasudevan et al. (2012) found that HP and EPSON have saved 65% cost from remanufacturing. In addition, remanufacturing can enhance a "green" brand image and limit competition from second-hand markets (Atasu et al., 2008; Souza, 2013). Therefore, remanufacturing is both an efficient way to reuse old products and an important sustainability strategy.

A growing number of firms (e.g., Caterpillar, Xerox, and HP) have introduced remanufacturing initiatives to gain competitive advantage (Martin et al., 2010; Ferguson, 2010). Moreover, reman products grew by 15% to $43 billion from 2009 to 2011 (U.S. International Trade Commission, 2012). Although reman products are comparable to new products (i.e., verified to perform as well as new products), the demand for reman products and consumers' willingness-to-pay for reman products are generally lower than those for new products, even if they are guaranteed to have the same quality (Guide and Li, 2010; Östlin et al., 2009).

Trade-in programs have traditionally served as a tactic to promote new products. For instance, Apple allowed consumers to trade in old iPods to receive 10% off for a new one (http://www.apple.com/recycling/ipod-cell-phone/). Retailers, such as Best Buy, Amazon and JD.com, also offer trade-in programs for a wide range of new products, including computers, monitors, and printers. These trade-in programs enhance a consumer's purchase intention and increase the demand for new products.

In order to boost the demand for reman products and promote the recycling of used products, some businesses and governments have started to implement "Trade-Old-for-Remanufactured" (TOR) programs, which encourage consumers to return used products for credits to purchase reman products. For example, Caterpillar, a firm renowned for remanufacturing, has adopted a TOR program, which not only promotes the sales of reman products, but also enhances the return of used products

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(Xu, 2014). Apple also launched reman/refurbished products whereby consumers can trade in their old products to receive gift cards for these products (http://www.apple.com/shop/browse/home/specialdeals). In 2015, the Chinese government initiated subsidies for TOR programs by giving cash to consumers who returned old products and purchased reman products.

In practice, TOR programs present new challenges for managers, as they are very concerned that reman products will cannibalize new product sales. Although they ultimately offer TOR programs, they must first make many complex decisions. For example, the prices of new and reman products, reman product receptivity, and new product durability may all significantly influence the demand for reman products. Moreover, product remanufacturability and government subsidy also affect the decisions of firms and consumers. Note that higher remanufacturability is associated with lower remanufacturing cost. The following important managerial questions surrounding TOR programs must be addressed:

(1) Under what operations/marketing conditions should a firm offer a TOR program?
(2) How to determine the optimal pricing and production quantity for a TOR program?
(3) How to incentivize consumers to participate in TOR programs?
(4) How do government subsidies affect a firm's decision and TOR performance?
(5) What benefits or detriments can TOR programs bring to firms, consumers, and the environment?

As the remanufacturing industry continues to grow, we must address these questions to help managers and policy makers make correct decisions and maximize TOR programs' potential. However, there is relatively limited theoretical or empirical exploration on this issue. To close this knowledge gap, we develop three dynamic firm-consumer games for various scenarios: (i) No-TOR program, (ii) TOR program without subsidy, and TOR program with subsidy. Through the development and comparison of these three models, we summarize our findings and derive the following insights:

(1) Despite the many benefits of reman products, not all firms should offer TOR programs. A firm should implement a TOR program when reman product receptivity and product durability meet a certain condition.
(2) When offering a TOR program, the firm should decide on the optimal pricing and production strategies by matching reman product's receptivity and the product's durability.
(3) Not only reman product receptivity but also product durability plays an important role in motivating consumers to participate in TOR programs.
(4) High product remanufacturability and government subsidy can significantly facilitate a firm to offer a TOR program.
(5) Although TOR programs may cannibalize new product sales, overall they can improve firm profitability, consumer surplus, and environmental sustainability, while government subsidies would further enhance such benefits.

The above management insights may help firms make right operational decisions to effectively manage TOR programs, and validate the use of government subsidy to maximize TOR programs' implementation and potential.

The rest of the paper is organized as follows. Section 2 reviews the related literature. Sections 3 and 4 introduce the model setup and develop analytical models for various TOR scenarios. Section 5 compares the model results. Numerical analyses are conducted in Section 6 to validate the theoretical results and to derive insights. Finally, Section 7 provides conclusions, limitations, and future research directions.

2. Literature review

Two streams of research are directly related to our research: (1) pricing and remanufacturing strategy for Closed-loop Supply Chains (CLSCs); and (2) managing trade-in programs. We next review each stream and position our paper accordingly.

2.1. Pricing and remanufacturing strategies of CLSCs

Various researchers have studied the pricing and remanufacturing strategies in CLSCs; see Souza (2013) for review. Ferrer (1996) studied the conditions under which the firm should offer two product types, just the new product, or just the remanufactured product. Majumder and Groenevelt (2001) proposed a two-period model where an original equipment manufacturer competed with a local remanufacturer. Savaskan et al. (2004) studied the choice of collection channel with assumption that the consumer didn't distinguish between new and reman products. Debo et al. (2005) optimized the manufacturer's decisions on pricing and remanufacturability level with third-party remanufacturers.

Similarly, Robotis et al. (2005) studied how to use the remanufacturing as a tool to serve secondary markets. Ferguson and Toktay (2006) studied the pricing and remanufacturing/collection decisions when facing a competing local remanufacturer. Ferrer and Swaminathan (2006, 2010) developed pricing strategies for new and differentiated remanufactured products. Atasu et al. (2008) considered the influence of green segment size, original equipment manufacturer (OEM) competition, and market growth rates. Mitra and Webster (2008) proposed a game-theoretic competition model for an OEM and a remanufacturer and found that government subsidy helps promote remanufacturing. Chen and Chang (2012) identified the conditions under which an OEM will choose a cooperative or a competitive approach in remanufacturing. Wu (2012) investigated the OEM's product design strategy and the remanufacturer's pricing strategy.

Recently, Örsdemir et al. (2014) found that remanufacturing will have a greater environmental benefit if the remanufacturer is an OEM. Han et al. (2016) investigated manufacturer's reverse channel selection for a closed-loop supply chain under remanufacturing risks. Mitra (2016) studied the competitive advantages of a manufacturer which sells remanufactured products in a duopoly environment.

The above literature obtained many interesting findings on optimal strategies for firms with remanufacturing. However, most of them assumed that customer purchase decisions are independent across periods and did not consider replacement behaviors of consumers. Differs from the above literature, we propose a two-period model with considering the replacement behaviors of the consumers under TOR programs.

2.2. Managing trade-in programs

Up to now, most current trade-in research focuses on “trade-old-for-new” programs. For example, Levinthal and Purohit (1989) showed that trade-in can prevent second-hand markets. Van Ackere and Reyniers, 1995 found that trade-in accelerated a consumer's replacement of existing products. Similarly, Adda and Cooper (2000) showed that forward-looking consumers buy in advance to take advantage of the discount in trade-in programs. Rao et al. (2009) found that trade-in programs reduced inefficiencies arising from the lemon (defective goods) problem, while Ma et al. (2013) examined the influence of consumption-subsidy of trade-in programs on consumers, the scale of the CLSC, and the enterprise. Fewer studies have investigated trade-in programs with remanufacturing (Heese et al., 2005; Ray et al., 2005; Agrawal et al., 2015; Miao et al., 2017). For example, Heese et al. (2005) analyzed the profitability of remanufacturing under direct OEM competition. They found that the first-moving firm should participate in product take-back and remanufacturing, as it can have advantages in production costs and market share to the detriment of its competitors.