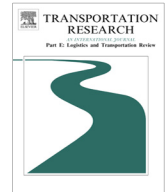




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Third-party remanufacturing mode selection: Outsourcing or authorization?

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ABSTRACT

Many original equipment manufacturers (OEMs) allow third-party remanufacturers (3PRs) to perform remanufacturing operations of branded or patented products – through either outsourcing or authorization. This study compares these two modes by modeling the game between the OEM and the 3PR on equilibrium quantities, prices, and profits. The results suggest that when consumers perceive the remanufactured products with a low value, the 3PR prefers the authorization approach; otherwise the 3PR prefers the outsourcing approach. However, in both scenarios, the OEM obtains higher profit through outsourcing than through authorization. Our further analysis compares two modes' impacts on consumer surplus, social welfare, and environment.

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1. Introduction

Compelled by environmental pollution and resource shortage, green legislations and financial instruments (e.g., green taxation and subsidies) hold original equipment manufacturers (OEMs) to be more responsible for their operations (Sheu, 2011). Remanufacturing, which can play a central role in these environmentally conscious industrial efforts, has become globally popular within a variety of industries (Webster and Mitra, 2007). Remanufacturing operations involve taking end-of-life (EOL) products, bringing them back to as-new condition, and selling them again, often with the same warranty as a new product (Atasu et al., 2010; Govindan et al., 2015). The restoring or recovering process tends to be energy-saving, less material-consuming, and often has a lower impact on environment than manufacturing brand-new products from virgin materials (Chen and Chang, 2012). Remanufacturing offers some very appealing potentials: enabling positive environmental outcomes while simultaneously increasing firm profits by extracting value from used items (Galbreth et al., 2013). Many OEMs who actively carry out remanufacturing operations have achieved satisfying results. For example, Caterpillar established a remanufacturing division which had over a business volume of \$2 billion in 2007 (Ferguson and Souza, 2010). Xerox saved 40–65% manufacturing costs through its green remanufacturing program (Savaskan et al., 2004).

In practice, the majority of remanufacturing operations are performed by third-party remanufacturers (3PRs) (Örsdemir et al., 2014). However, two different options/modes exist for OEMs: outsourcing remanufacturing and authorization

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remanufacturing. In the outsourcing remanufacturing operations model, a 3PR only performs the remanufacturing operations, and the marketing of the remanufactured products is still performed by the OEM itself. In the US and Europe, many OEMs prefer to outsource remanufacturing operations (Karakayali et al., 2007). Ferguson and Souza (2010) stated that there has been a significant trend over the last 30 years for OEMs to outsource and offshore their manufacturing operations. These OEMs not only outsource new product manufacturing but also their remanufacturing operations to outside contractors. For example, Land Rover and Caterpillar signed an agreement where Caterpillar Remanufacturing Services will act as Land Rover's lead global remanufacturing services provider (The Auto Channel, 2005). In contrast, authorization remanufacturing refers to the practice in which a 3PR acquires the proprietary rights from the OEMs to remanufacture EOL products and resell the remanufactured products without the involvement of the OEM. Such practice has gained momentum in some developing countries in recent years because there is increasing awareness of remanufacturing's potential benefits (Wang et al., 2014). For example, in 2010, China's National Development and Reform Commission (CNDRC) announced that Chinese government would pay special attention to the development of remanufacturing industry (China Remanufacturing, 2015). As of 2013, twenty-eight remanufacturers had been approved by CNDRC with majority of them being 3PRs, and most of them conduct their business with the authorization remanufacturing approach (National Development and Reform Commission, 2015). In 2015, Apple signed an agreement with Foxconn in which the latter acquires the proprietary rights to remanufacture the EOL iPhone mobile phones and remarket them in the Chinese market (Xi'an Civilization Network, 2015). However, it is unclear that which of the two remanufacturing modes (outsourcing and authorization) is a better choice. Our literature search revealed that extant research has not compared these two approaches and provided meaningful guidelines on how to select the most appropriate remanufacturing mode.

In order to address this apparent research gap and advance our understanding of this topic, we use the game theory approach to develop two alternative third-party remanufacturing modes in which the OEM can either outsource remanufacturing operations to the 3PR or authorize the 3PR to remanufacture and resell the EOL products. We analyze and compare these two remanufacturing modes from both the OEM's and the 3PR's perspectives. In addition, we also compare consumer surplus, social welfare, and environmental impacts related to the two modes.

The rest of this paper is organized as follows. After reviewing relevant literature in Section 2, we introduce two remanufacturing models in Section 3. Section 4 solves the equilibrium in these two models. Section 5 presents a comparison of equilibrium results, the consumer surplus, the social welfare, and environmental impact between the two remanufacturing modes. Additional numerical experiments are presented in Section 6, which is followed by the conclusion and implications in Section 7.

2. Literature review

We limit our review to the literature closely related to the topic of interest. Firstly, the literature of channel selection is pertinent to our study. Existing research of channel selection mainly focuses on the impacts of different marketing channels or operation channels on supply chain members' operations or profits. Some studies have investigated the channel selection issue in the remanufacturing area. For example, Savaskan et al. (2004) compared three options of collecting EOL products and found that the retailer is the most effective undertaker of EOL product collection operations. Savaskan and Van Wassenhove (2006) later verified that such result is still valid when retailers compete on prices. Recently, Yan et al. (2015) studied two options to market remanufactured products: marketing through the company's own e-channel or subcontracting the marketing operation to a third party. They found that both the OEM and the retailer prefer subcontracting to a third party although marketing through its own e-channel has less environment impacts. In our paper, we also compare these two marketing options. However, the key difference between our study and their research is that in Yan et al.'s (2015) study, it is the OEM who carries out the remanufacturing operation, but in our study it is a third party who performs this operation. The scenario in our study is a more common arrangement in practice, and we therefore believe our study has wider implications to practices.

In addition, two other remanufacturing research streams are also relevant to our study. One is about outsourcing remanufacturing operations. Savaskan et al. (2004) found that outsourcing the EOL product collection process to a retailer is more effective than doing it by the OEM itself or a third party. Ordoobadi (2009) presented a multi-phased decision model for strategic analysis of outsourcing remanufacturing operation in which a comprehensive tool for effective decision making by considering both economic and strategic factors. Karakayali et al. (2007) considered two decentralized collection and remanufacturing modes – remanufacturer-driven channel and collector-driven channel, and identified situations in which each mode will be the best option for the OEM. Ferguson and Souza (2010) pointed out that because many OEMs lack the infrastructure and expertise to collect and remanufacture EOL units in a profitable manner, and thus they would outsource the remanufacturing to outside contractors. Ferrer and Whybark (2001) described several tradeoffs between conducting remanufacturing within an OEM's own plants or facilities and outsourcing remanufacturing to third parties. Tsai et al. (2007) discussed cost savings resulted from the remanufacturing outsourcing decision and concluded that the more the firm is uncertain about the costs and the inputs of materials, unit- and batch-level activities, the more it might benefit from the information of costs transferred by the outsourcing partner (Zhu, 2015). In a scenario where the OEM outsources the recycling operation to a third party, Zhang et al. (2015) constructed a dynamic game model and demonstrated that government subsidy to the OEM instead of the third party will improve recovery rate.

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