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RETAILER OR THE THIRD-PARTY REMANUFACTURER: WHICH IS THE GREENER CONTRACTOR FOR OUTSOURCING REMANUFACTURING?*

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Abstract. The aim of this paper is to understand how outsourcing remanufacturing operations to different OEMs agents (i.e., the retailer or third-party remanufacturer) affected a supply chain's sustainable issues. Although outsourcing strategies have been well studied in the remanufacturing literature, existing research has focused primarily on operational options between original equipment manufacturers (OEMs) and third-party remanufacturers (3PRs). In practice, however, many brand name retailers have recently created business models in which product remanufacturing is an integral part. The question showed the retailer or the third-party, which was the right remanufacturer for OEM's remanufacturing outsourcing? To answer this question, we developed two models for an OEM that had two options for remanufacturing outsourcing: (1) outsourcing remanufacturing to a 3PR (Model T) or (2) to its retailer (Model R). Using these two models, we addressed the questions: from the profit-maximizing perspective, how does outsourcing remanufacturing operations to retailers create strategic issues that are different from those with 3PRs? Which is more profitable for the OEM, 3PR, retailer, and the total supply chain? From an environmental impact perspective, how does outsourcing remanufacturing operations to retailers create strategic issues different from those with 3PRs? Which is more beneficial for our environment? Our analysis revealed that if the OEMs cared about economic performance, outsourcing the remanufacturing operations to the 3PR was a practical strategy. Conversely, if they cared about environmental sustainability, outsourcing the remanufacturing to the retailer was the preferred strategy. Numerical studies further validated our conclusions

Keywords: outsourcing; third-party remanufacturer; original equipment manufacturer; greener contractor

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1. Introduction

Besides the fact that remanufacturing creates benefits for the economy and the environment, it also poses several questions for original equipment manufacturers (OEMs) when they intend to undertake remanufacturing operations themselves. The greatest concern for the OEM is the risk of cannibalization problems between remanufactured and new products. The consumers' willingness to pay for the remanufactured consumer product was usually 15.3% lower than that for the new one (Guide and Li, 2010). The loss of profits from new product sales is not the only concern for OEMs when undertaking remanufacturing operations. In practice, many customers associate the lower quality of a remanufactured product with the OEM's brand, making it even more difficult for OEMs to maintain a high-quality branding image when adopting remanufacturing as part of its extended business (Ferguson, 2010; Fedorko et al. 2018).

As a result, many OEMs prefer to outsource remanufacturing operations (Karakayali et al., 2007). For example, in developed countries, such as the U.S. and European nations, many brand name OEMs, such as IBM, Texas Instruments, Hitachi, and Dow, have outsourced their remanufacturing operations to other agents, which earned millions of dollars in licensing revenues (Arora et al., 2013). According to a survey from the U.S. remanufacturing industry, OEMs only accounted for a small fraction (about 6%) of the total firms with integrated remanufacturing operations (Hauser and Lund, 2003). Similar cases also appeared in developing countries. For example, in 2008, the pilot program for automobile parts remanufacturing entered into force in the China market. In this pilot program and several OEMs, many third-party remanufacturers (3PRs) supported by the China National Development and Reform Commission selected to engage in remanufacturing for auto parts (National Development and Reform Commission, 2022).

Besides, it noted that many brand name retailers had created business models in which product remanufacturing was an integral part (Fedorko et al. 2018; Radavičius et al., 2021; Horvath et al. 2021). For example, Argos repositioned itself by offering affordable leasing of all its products by requiring recycling or remanufacturing when those products reached their end-of-life stage (The Brands of the Future Must Be Sustainable, 2021). Similarly, TigerDirect offers remanufactured products (TigerDirect Refurnished), such as printers, laptops, cameras, Led monitors, and more. For example, in the Chinese market, Sevlao, the largest distributor for excavators in China, has established its production-batch process of disassembly, cleaning, refurbishment, and replacement for excavators. From a research perspective, the discussion above raises the fundamental question addressed in this paper. Are the effects on profits or sustainability different if the OEM outsources remanufacturing operations to its retailers but not to 3PRs?

Profits or sustainability issues are perhaps the two important components that affect the selection of an OEM's remanufacturers (Ferguson, 2010; Mezulanik et al., 2020; Dvorsky et al., 2020). Indeed, outsourcing remanufacturing operations to 3PRs not only allows OEMs to focus on the production of new products, sales, and marketing, but it also outsources the "extended producer responsibility" of the end-of-life products to 3PRs. However, we should note that such an outsourcing strategy creates a secondary remanufactured market that is not under the OEM's direct control but is a niche for 3PRs. In the I.T. industry, "third-party companies built over \$100 million per year businesses in buying used computer equipment, remanufacturing it, and selling or leasing it out to someone else" (Big players emerge in fragmented brokerage market, 2021). Of course, such large numbers of remanufactured products from 3PRs can have serious consequences for OEMs' new product prices and profitability. Conversely, outsourcing remanufacturing operations to retailers is a potential option that mitigates the competition from the remanufactured product's market because both parties, including retailers, were concerned about the cannibalization problems of remanufactured products. However, such outsourcing may

induce considerable challenges for the OEM's profitability from new products and their branding image (Yan et al., 2015).

Our goal in this paper was to understand how outsourcing remanufacturing operations to different OEMs agents (i.e., the retailer or third-party remanufacturer) affected a supply chain's sustainable issues. More specifically, we developed two models for an OEM that have two options for remanufacturing outsourcing: (1) outsourcing it to a 3PR (Model T) or (2) outsourcing it to its retailer (Model R). Using these two models, we addressed the following questions.

1. From the profit-maximizing perspective, how does outsourcing remanufacturing operations to retailers create strategic issues that are different from those with 3PRs? Which is more profitable for the OEM, 3PR, retailer, and the total supply chain?
2. From an environmental impact perspective, how does outsourcing remanufacturing operations to retailers create strategic issues different from those with 3PRs? Which is more beneficial for our environment?

The overall contribution of this paper is threefold. First, instead of highlighting the interactions between the OEM and the 3PRs related to outsourcing remanufacturing, we allowed the OEM to have the potential flexibility to outsource remanufacturing to its retailers. Second, our work investigated the OEM's decisions that involved choosing the "right" remanufacturer and demonstrated how it affected the supply chain's economic outcomes and how environmental sustainability was affected by this flexibility. Finally, our paper sheds new light on the remanufacturing outsourcing model, which revealed that outsourcing remanufacturing operations to the 3PR were advantageous if the OEMs cared about economic performance. On the other hand, if they cared more about environmental sustainability, outsourcing remanufacturing operations to the retailer was the preferred strategy.

This paper proceeds as follows. In section 2, we reviewed related literature on remanufacturing outsourcing and on closed-loop supply chains. In section 3, we introduced our basic assumptions. In section 4, we presented and solved our two models. In section 5, we examined the effects of OEM outsourcing of its remanufacturing to different agents and explored the main results related to sustainable issues. Furthermore, in §6, we discussed the results and provided several possible directions for future research.

2. Literature Review

This paper complements the literature on remanufacturing, where we observed the remanufacturing outsourcing strategy between the OEM and the 3PRs. For example, Majumder et al. (2001) showed that, under a certain condition, the 3PR had incentives to reduce the OEM's remanufacturing cost. Debo et al. (2005) found OEM's optimal level of remanufacturing was lower than the monopoly model and decreased as the number of competing remanufacturers increased. Subsequently, Ferrer et al. (2006) found that, as the threat of competition increased, the OEM was more likely to utilize all available cores completely. Recently, Wu et al. (2006) presented an argument that competing OEMs without remanufacturing capacity sometimes benefited from the entry of 3PRs. Meanwhile, Zou et al. (2016) showed that it was in society's interest if the OEMs outsourced remanufacturing to 3PRs. Although most of the above research analyzed the remanufacturing outsourcing relationships between the OEM and the 3PRs, they ignored the OEM's potential flexibility to choose other remanufacturers, such as retailers. In contrast, we developed two models that allowed the OEM to have the flexibility to outsource remanufacturing to its retailers or 3PRs. Thus, we complement the above literature on remanufacturing outsourcing strategy between the OEM and the 3PRs by addressing how the flexibility of the OEM to outsource remanufacturing to a TPR or its retailers affected the issue of environmental performance in a supply chain.

This paper also relates to the literature that highlights the retailer's role in the closed-loop supply chain. Savaskan et al. (2004) addressed choosing the appropriate reverse channel structure to collect used products from customers. Recently, Shulman et al. (2010) examined how the return penalty was affected when returns were

either salvaged by the OEM or by the retailer. They found that the return penalty was more severe when returns were salvaged by a channel member who derived greater value from a returned unit. Subsequently, Lee et al. (2011) presented a model that integrated operations decisions with the retailer's collection and showed that the retailer retained the same form of decision-making by identifying an analogous closed-loop production efficiency. Although the above research highlighted the role of retailers in the reverse channels for collecting the end-of-life products, they ignored the fact that, in recent years, many retailers have created business models in which product remanufacturing was an integral part. Shi and Min (2014) discussed the possibilities of remanufacturing products. Fees for remanufacturing or disposal of goods are in some cases paid for by the government. This economic government instrument can also have a major impact on the environment. Golinska (2014) also notes that remanufacturing is a step towards resource efficiency and can lead to the sustainability of the whole business. According to Kasych et al. (2019) it is important that society and the economy of the whole country are sustainable in terms of economic, environmental and social components. According to Li et al. (2013) the remanufacturing of goods and their subsequent sale is very risky for companies, because they never know in what condition the merchandise will arrive and what the profit will be from a particular remanufactured item after deducting all the costs of remanufacturing. The remanufacturing process itself can also be a marketing strategy that deprives producers' market share of price discrimination (2008). Remanufacturing older products at the end of their service life may prevent new products from entering the competition. However, within a company, remanufacturing poses a risk of preventing the entry of new products, such as newer technologies used and offered for sale at higher margins (Atasu et al., 2006; Bacik et al. 2018). However, in most cases, companies face management barriers, preventing them from initiating remanufacturing services (Gavurova et al. 2018). However, this problem could be eliminated if management activities were left to the model of artificial neural networks. According to Vrbka and Rowland (2020) it is possible to leave the decision of the managerial character of the company to a computer system. According to Geyer et al. (2007) it is important to carefully coordinate the structure of production costs of a new product in order to save on the costs of its subsequent remanufacturing. Zikopoulos and Tagaras (2007) also emphasize that when remanufacturing a product, transporting it to a third-party remanufacturing is one of the most costly expenditures in the entire remanufacturing process. According to Agrawal et al. (2015). The offering of remanufactured products that have been remanufactured by the manufacturer may reduce the perceived value of the new product offered by up to 8%. Conversely, offering remanufactured products that have been remanufactured by a third party may increase the perceived value of the new products offered by up to 7%. Fang et al. (2019) states that a manufacturer should leave the remanufacturing of its products to a third party if this would mean a reduction in the manufacturer's profits. According to Shu et al. (2016), for the optimization of the supply chain in which both new products and remanufactured products figure, there is an important difference in the distribution costs of individual product types (new/refurbished). Suppliers should also focus on products with lower manufacturing/remanufacturing costs. According to Ovchinnikov (2011), the behavior of consumers when buying remanufactured products is very different from the standard behavior when buying new products, and therefore standard predictive sales methodologies for new products cannot be used to predict the sales of remanufactured products.

The whole issue of new products vs. remanufactured products is also greatly affected by consumers' willingness to pay. According to Chen et al. (2019) consumers' willingness to pay for remanufactured products varies depending on age, education, occupation, consumer income and other individual preferences (interest in the environment, antiquarian preferences, trust in a particular brand). Another important parameter is also the perception of the product itself (risk of buying a remanufactured product, goodwill of the brand). Michaud and Llerena (2011) consider remanufactured products to be green products. However, consumers are not willing to pay more for a so-called green product than for a conventional product. If the seller informs the consumer that by purchasing a remanufactured product, the consumer can make a positive contribution to the environment, consumers' willingness to pay increases. Dai et al. (2020) addressed the differentiation of consumers' willingness to pay depending on the offering of remanufactured products. Consumers' willingness to pay varies depending on Corporate Social Responsibility. In setting the right price for remanufactured products, consumers' willingness to

pay is within reasonable limits and there is no surplus or shortage, which helps to sustain the development of the economy. The perceived value of remanufactured products to consumers is very important, as high consumers' willingness to pay can be detrimental to producers (Fang et al., 2019). The willingness to buy a remanufactured product is also given by the so-called "green image" of the company (Georgiandis, 2004).

Raz et al. (2017) used an analytical model and a behavioral study to determine the degree of cannibalization of demand between individual companies that offer remanufactured products and that do not. remanufactured products create a surplus for consumers that offset the cost of environmental impact. According to Esenduran et al. (2016) legislation in the framework of forced end-of-life product buybacks may not be as environmentally beneficial as it may seem at first sight. Remanufacturing large quantities of products can thus be very burdensome for the environment. Chen et al. (2020) point out that legislation assesses a company's environmental performance on the basis of the amount of carbon emitted into the atmosphere. However, the amount of carbon emitted during the disposal process must also be taken into account when remanufacturing products. In relation to the environment, Cerda (2011) examined consumers' willingness to pay in the analysis of contributions to the rescue of an ecologically endangered area from its visitors. It can also be used to determine the economic value of this otherwise ecologically important area. According to Pimonenko et al. (2020), in line with the new trend, companies should transform their overconsumption into green consumption. With this marketing strategy, companies can also increase the value of their products and become more attractive to consumers and investors.

Based on observations from current practice, we developed two theoretical models in which the retailer actively engaged in remanufacturing operations. Therefore, our work contributes to the prior literature by allowing the retailer the flexibility to undertake the remanufacturing operations, which is consistent with earlier observations from current practice.

3. Model Notations and Assumptions

In this study, we considered two different supply chain models with two options for the OEM's remanufacturing outsourcing: (i) Model T (Figure 1(a)), where the OEM outsources the remanufacturing to the 3PR, and (ii) Model R (Figure 1(b)), where the OEM outsources the remanufacturing to the retailer. We discuss and layout our key assumptions below.

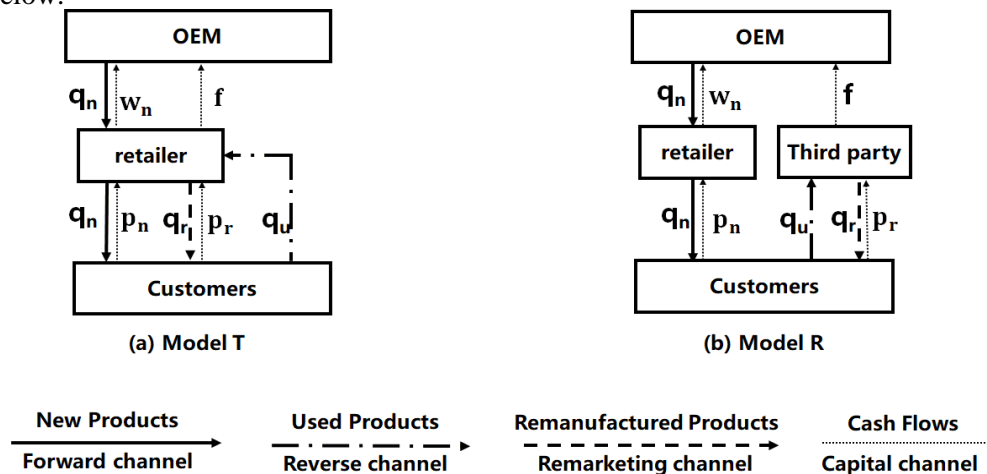


Figure 1. The two basic scenarios of remanufacturing outsourcing.

Source: Authors.

Assumption 1. The unit cost of remanufacturing a used core (c_r) is lower than that of producing a new product (c_n) (i.e., $c_r < c_n$).

This assumption is quite common in the literature on remanufacturing (Yan et al., 2015; Zou et al., 2016, Savaskan et al., 2004). This assumption was supported by Giutini and Gaudette (2003), who confirmed that the costs of remanufacturing accounted for 40-65% of traditional manufacturing.

Assumption 2. Consumers are heterogeneous in their willingness to pay (v) for the new product, uniformly distributed in $[0, Q]$.

The assumption that the consumer's willingness-to-pay for the new product is heterogeneous and uniformly distributed in $[0, Q]$ is widely-accepted in modeling the consumers' heterogeneity (see Ferrer et al., 2010).

Assumption 3. The willingness to pay for each consumer is measured by the ratio of a remanufactured product to the new product is γ ($0 \leq \gamma \leq 1$).

The vertical heterogeneous acceptance of new and remanufactured products in Assumption 3 is consistent because consumers' willingness to pay for the remanufactured consumer product is 15.3% lower than that for the new product (Guide and Li, 2010). Based on the consumer utility functions in Assumptions 2 and 3, the demand functions for new and remanufactured products can be derived. We provide the detailed derivations of them in the Appendix A-I.

$$q_n = \frac{(1 - \gamma)Q - p_n + p_r}{\frac{(1 - \gamma)}{\gamma p_n - p_r}}, \quad (1)$$

$$q_r = \frac{\gamma p_n - p_r}{\gamma(1 - \gamma)}.$$

This linear demand function is quite common in the remanufacturing literature (Savaskan et al., 2004), Ferguson and Toktay (2006)). It should be noted that the consumer value discount for the manufactured products reflects the potential for reducing problems between both products.

Assumption 4. In a steady-state period, the sequential-move games in both models are as follows: the OEM first announces the wholesale price/patent license fee (w_n/f), and the retailer third-party determines the optimal units of new or remanufactured products (q_n or q_r).

A relicensing fee has been widely employed by the OEM when it outsources the remanufacturing to other third party establishments (Zou et al., 2016; Oraopoulos et al., 2012). One can think of f as the unit technical fees charged based on the OEM licenses for remanufacturing technology to others. Finally, like Yan et al. (2015) and Xiong et al. (2013), we assumed that all players had access to the same information. All related notations are presented in Table 1.

Table 1. Parameters and definitions related to this paper

Notation	Definition
w_n / f	The unit wholesale price/ patent license fee charged for a new and remanufactured product
c_n / c_r	The average unit cost of manufacturing new/remanufactured products
p_n / p_r	The unit retail price for a new/remanufactured product
q_n / q_r	The total sales of new/remanufactured products
π_i	Profits of the player i

Source: Authors.

4. Model Formulation and Solution

This section introduces our two models—Model T, in which remanufacturing is outsourced to a 3PR, and Model R, where the retailer undertakes the OEM's remanufacturing. In the following analysis, subscript $i \in \{m, r, 3p, t\}$ refers to the OEM, retailer, 3PR, and the total supply chain, respectively; superscript $j \in \{T, R\}$ denotes Model T and Model R, respectively.

In Model T, the remanufacturing is undertaken by the 3PR, but the OEM produces all new products. Thus, the OEM's problem is

$$\max_{w_n, f} \pi_m^T(w_n, f, p_n^*, p_r^*) = (w_n - c_n)q_n + f q_r \quad (2)$$

Given the wholesale prices w_n and the patent license fees f the retailer's and the 3PR's problem is

$$\begin{aligned} \max_{p_n} \pi_r^T(w_n, f, p_n, p_r) &= (p_n - w_n)q_n \\ \max_{p_r} \pi_{3p}^T(w_n, f, p_n, p_r) &= (p_r - c_r - f)q_r \end{aligned} \quad (3)$$

The above interaction can be analyzed using backward induction: the retailer/remanufacturer maximizes its profit by choosing p_n^{T*}/p_r^{T*} , but the OEM can choose w_n^{T*} and f^{T*} (Table 2). All technical details and proofs appear in the Appendix.

In Model R, the OEM's remanufacturing is outsourced to the retailer. As a result, in addition to selling new products, the retailer should determine the number of remanufactured products according to the OEM's relicensing fee. As a result, the OEM's and the retailer's profit can be written as

$$\begin{aligned} \max_{w_n, f} \pi_m^R(w_n, f, p_n^*, p_r^*) &= (w_n - c_n)q_n + f q_r \\ \max_{p_n, p_r} \pi_r^R(w_n, f, p_n, p_r) &= (p_n - w_n)q_n + (p_r - c_r - f)q_r \end{aligned} \quad (4)$$

Solving the FOCs of the retailer's profits and then substituting them into the OEM's profit in the equation (4) provides the equilibrium outcomes in Model R (Table 2).

Table 2. Equilibrium decisions and profits

The Third-party engages in remanufacturing (Model T)	
$w_n^{T*} = \frac{Q + c_n}{2}$	
$f^{T*} = \frac{\gamma Q - c_r}{2}$	
$q_n^{T*} = \frac{c_n \gamma^2 - 2c_n - 2Q\gamma + 2Q + c_r}{2\gamma^2 - 10\gamma + 8}$	
$q_r^{T*} = \frac{(Q + c_n + c_r)\gamma - Q\gamma^2 - 2c_r}{2\gamma(\gamma^2 - 5\gamma + 4)}$	
$p_n^{T*} = \frac{6Q + 2c_n + c_r - 3Q\gamma}{2Q\gamma^2 - 2c_r - 5Q\gamma - c_n\gamma}$	
$p_r^{T*} = \frac{2(4 - \gamma)}{2c_r^2 - c_r^2\gamma - c_n^2\gamma^2 + 2c_n^2\gamma - 2c_n c_r \gamma - Q^2\gamma^3 - Q^2\gamma^2 + 2Q^2\gamma + 4c_n Q\gamma^2 - 4c_n Q\gamma + 2Q c_r \gamma^2 - 2Q c_r \gamma}$	
$\pi_m^{T*} = \frac{4\gamma(4 - \gamma)(1 - \gamma)}{(2Q - 2c_n + c_r - 2Q\gamma + c_n\gamma)^2}$	
$\pi_r^{T*} = \frac{4(4 - \gamma)^2(1 - \gamma)}{(Q\gamma - 2c_r + c_n\gamma + c_r\gamma - Q\gamma^2)^2}$	
$\pi_{3p}^{T*} = \frac{(Q\gamma - 2c_r + c_n\gamma + c_r\gamma - Q\gamma^2)^2}{4\gamma(4 - \gamma)^2(1 - \gamma)}$	
The retailer engages in remanufacturing (Model R)	
$w_n^{R*} = \frac{Q + c_n}{2}$	
$f^{R*} = \frac{\gamma Q - c_r}{2}$	
$q_n^{R*} = \frac{Q - 2Q\gamma - c_n + c_r}{4(1 - \gamma)}$	
$q_r^{R*} = \frac{c_n\gamma - c_r}{4\gamma(1 - \gamma)}$	
$p_n^{R*} = \frac{3Q + c_n}{c_r + 3Q\gamma}$	
$p_r^{R*} = \frac{\gamma Q^2 - Q^2\gamma^2 + 2\gamma^2 Q c_n - 2\gamma Q c_n + \gamma c_n^2 - 2\gamma c_n c_r + c_r^2}{8\gamma(1 - \gamma)}$	
$\pi_m^{R*} = \frac{Q^2\gamma - Q^2\gamma^2 + 2Q c_n\gamma^2 - 2Q c_n\gamma + \gamma c_n^2 - 2c_n c_r \gamma + c_r^2}{16\gamma(1 - \gamma)}$	
$\pi_r^{R*} = \frac{Q^2\gamma - Q^2\gamma^2 + 2Q c_n\gamma^2 - 2Q c_n\gamma + \gamma c_n^2 - 2c_n c_r \gamma + c_r^2}{16\gamma(1 - \gamma)}$	

Source: Authors.

To ensure accurate comparison of the interior point solutions for both models(i.e., $0 < q_r < q_n$, as seen in Yan et al. (2015) and Xiong et al. (2013), we derived the following assumption (see Lemma 1 and its proof in the Appendix).

Assumption 5. In both of our models, the cost of remanufacturing a core was not sufficiently small or large; that is, $\frac{\gamma(Q\gamma + 3c_n - Q - c_n\gamma)}{2} < c_r < \gamma c_n$.

5. Results - Analysis

This section addressed the question posed at the beginning of this paper: Retailer vs. third-party, who is the right remanufacturer for OEM's remanufacturing outsourcing? To do so, we analyzed the difference in equilibrium decisions between both models. Subsequently, we enriched our analysis to capture the difference in sustainability between both models based on economic and environmental outcomes.

5.1 Comparison of Optimal Outcomes

Based on the equilibrium outcomes of both models, we first derived some key insights into the difference in optimal decisions between the models, which is summarized in the following proposition:

Proposition 1. Compared to Model R, there was a larger quantity of both products in Model T; that is, $q_n^{T*} > q_n^{R*}$ ($q_r^{T*} > q_r^{R*}$).

In Model T, we mentioned earlier that the 3PR was an independent player whose total profits were derived from remanufacturing. As a result, the 3PR independently sought to maximize its profit by remanufacturing and cared nothing about the potential to reduce sales of new products by selling remanufactured products. However, in Model R, both new and remanufactured products were available from the retailer. As a result, the retailer should care greatly about the profits from remanufactured products and be concerned about the cannibalization of new product sales. As Proposition 1 showed, compared with Model R, the availability of remanufactured products in Model T increased, which resulted in significant cannibalization problems for new product sales and reduced the price of new products. Confronting such fierce competition from the remanufactured market, the retailer has to offer more new products under such a scenario to offset each new product's loss of price. That is, confronting a decrease in wholesale price, the retailer would provide higher sales volumes of remanufactured products to offset each new unit's loss.

5.2 Comparison of Profitability

In this section, we examined the OEMs' flexibility regarding how outsourcing affected all parties' profitability. That is, from the profit-maximizing angle, how did outsourcing remanufacturing operations to retailers create strategic issues that were different from those with 3PRs? Which was more profitable for the OEM, 3PR, retailer, and the total supply chain? To do so, we compared the profitability of the OEM, 3PR, retailer, and the total supply chain of Model T with those of Model R. We first turned our attention to the difference in OEM's profitability between both models.

Proposition 2. The OEM benefited more in Model T than in Model R; that is, $\pi_m^{T*} > \pi_m^{R*}$.

The availability of remanufactured products in the market impacted the OEM's profits in two opposing ways. On the one hand, the more that remanufactured products were available in the market, the larger the OEM profits obtained due to the cost savings. On the other hand, as the number of remanufactured products increased, there was the potential to reduce new product sales as remanufactured products' sales intensified. Then, it led the OEM to derive less from new product sales. As a result, the underlying intuition behind Proposition 2 is as follows. If the OEM outsourced the remanufacturing operations to the 3PR, the first component dominated because the increasing availability of remanufactured products not only increased the profitability from remanufactured products, but it also made the competition between both downstream agents (i.e., the retailer and the 3PR) intensify, which mitigated the double marginalization problems in both distribution channels.

Note that, compared with Model R, the competition from the remanufactured products became fiercer in Model T. As such, Proposition 2 revealed that the OEM benefited from the entry of 3PRs, which was an argument supported by Mitra and Webster (2008), who demonstrated that competition from 3PRs usually generated higher

profits for the OEM. It should be noted that they focused on the scenario where an OEM made and sold a new product and a 3PR who competed with the OEM. In contrast, we assumed that the relationship between the OEM and the 3PR was a paradoxical phenomenon of co-opetition: on the one hand, they needed to work together in the remanufacturing market; on the other hand, they defended each other in two different (new and remanufactured products) markets.

We are now able to address how different outsourcing strategies for remanufacturing operations affected the retailer's profitability. Based on the outcomes in Table 2, we summarized our findings in the following proposition.

Proposition 3. Outsourcing the remanufacturing operations to the 3PR was always detrimental to the retailer; that is, $\pi_r^{T*} < \pi_r^{R*}$.

The underlying intuition behind Proposition 3 is as follows. In Model R, the remanufacturing operations were undertaken by the retailer. As a result, in this setting, its profits came from two sources: selling new products and providing remanufactured products. However, in Model T, the remanufacturing was undertaken by the 3PR. As a result, the latter revenue was transferred to the 3PR. Nevertheless, as shown in Proposition 1, the retailer's sales volume of new products was lower than that in Model T because it was a monopolist provider in Model R; in Model T, the retailer had to manage competition from the 3PR.

To analyze the effects of the OEM outsourcing the remanufacturing to different agents, it is of interest to compare the results in Propositions 2 and 3 with the results from Mitra and Webster (2008) where an OEM made a new product, and a 3PR competed with the OEM by remanufacturing used cores. There were two ways in which to make this comparison. The first was to compare the relationship between the OEM and the 3PR. From this perspective, we concluded that, although the competition from 3PRs was detrimental to new products' sales (see Proposition 1), such competition usually generated higher total profits for the OEM (see Proposition 2). From the OEM's perspective, outsourcing the remanufacturing in the Mitra and Webster model to the 3PR confirmed that remanufacturing from 3PRs led to an increase in both parties' profits.

Alternatively, we compared the relationship between the retailer and the 3PR to both firms' relationship in the Mitra and Webster model. From this perspective, we concluded that the competition from the 3PR was not only detrimental to the sales of new products (see Proposition 1), but it also generated lower profits for the retailer (see Proposition 3). From the retailer's perspective, outsourcing the remanufacturing in the Mitra and Webster model to the 3PR reversed that the remanufacturing from 3PRs led to an increase in both parties' profits. The reason for the reversal was analyzed in Proposition 3 and is not repeated here.

We provide the following proposition regarding the variations in total supply chain profits and how different outsourcing strategies for remanufacturing operations affected the total supply chain performance.

Proposition 4. Outsourcing the remanufacturing operations to the 3PR was always beneficial for the total supply chain; that is, $\pi_t^{T*} > \pi_t^{R*}$.

We proved in Proposition 4 that the total supply chain benefited more in Model T than in Model R. Compared with Model R, the increase in total supply chain profitability under the scenario of outsourcing remanufacturing operations to the 3PR was caused by the increase in competition between both downstream agents and the reduction in the double marginalization problems in both channels. Although outsourcing the remanufacturing to the third-party was detrimental to the retailer (see Proposition 3), this outsourcing strategy was beneficial for both

the OEM and the 3PR. Furthermore, both parties' benefits were large enough that it sufficiently compensated for the loss in the retailer's profitability.

5.3 Discussion and Comparison of Environmental Impacts

In this subsection, we address the last question posed at the beginning of the paper: From an environmental impact perspective, how do outsourcing remanufacturing operations to retailers create strategic issues different from those with 3PRS? Which is more beneficial for our environment?

According to ISO14040 (2006) and ISO14044 (2006), Life Cycle Assessment (LCA) is the "compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle." LCA is a quantitative method to calculate the environmental impact of a strategy by summing over all the life cycle phases from raw materials' procurement to end of life (White et al., 1999). LCA methodology can be used to evaluate the environmental performance of materials, products, and industries. A detailed literature review on LCA techniques in the remanufacturing industry is available (Suhariyanto et al., 2017; Atasu et al., 2013).

Consistent with previous work (Atasu et al., 2013; Liu et al., 2017), we measured the total environmental impacts per product by considering the four life cycle phases of production, use, remanufacturing, and disposal. Accordingly, we used i_n , i_u , i_r , and i_d to represent the per-unit impact of production, use, remanufacturing, and disposal, respectively. It should be noted that the remanufacturing operations can extend the life cycle of the new products, which resulted in the total environmental impact of use by consumers as $e_u = i_u(q_n + q_r)$. Also, because all products are disposed of in landfills after the usage without remanufacturing or after usage with remanufacturing, then the total environmental impacts of disposal should be $e_d = i_d q_n$. As a result, we obtained the total environmental impact as $e = i_n q_n + i_u(q_n + q_r) + i_r q_r + i_d q_n$.

Let E^T/E^R represent the environmental impact under the strategy of outsourcing remanufacturing to the 3PR/retailer (Model T/R), respectively. Then, we summarized our main results on environmental outcomes in the following proposition.

Proposition 5. Outsourcing the remanufacturing to the retailer was a greener strategy than outsourcing it to the 3PR; that is, $E^T > E^R$.

Note that there are two components behind Proposition 5: On the one hand, there is a larger quantity of new products in Model T; that is, $q_n^{T*} > q_n^{R*}$ (see Proposition 1), which means that the environmental impact of the life cycle phases of production (of new products), use (of new products), and disposal (of end of life products) in Model T were larger than that in Model R. On the other hand, Proposition 1 further revealed that compared with Model R, there was a larger quantity of remanufactured products in Model T, which meant that the remanufacturing level in Model T was higher than that in Model R. Moreover, the environmental impact of the life cycle phases of use (of remanufactured products) and remanufacturing in Model T was higher than that in Model R.

Conclusions

In recent decades, environmentally-friendly solutions and green operations have emerged as a growing topic. One of the lasting effects of the movement is that remanufacturing is generally perceived as a profitable and environmentally-friendly, end-of-use management option for many products. Although outsourcing has been well studied in the remanufacturing literature (Zou et al., 2016, Abdulrahman et al., 2017, Zhu, 2016, Strakova et al., 2020), existing research focuses primarily on the outsourcing strategy between the OEM and the 3PRs. However, it ignores that the retailer has the flexibility to engage in remanufacturing. However, in recent years,

many brand name retailers have created business models in which product remanufacturing is an integral part. Moreover, the effects on sustainability or profits are different if the OEM outsources remanufacturing operations to its retailers but not to 3PRs. Resource sustainability and business development is key to the future and the businesses themselves (Strakova et al., 2021a). However, to achieve this goal is important synthesis models based on the business environment. This fact is strongly essential (Strakova et al., 2021b; Strakova et al., 2018).

To answer the initial question, we developed two models for the OEM's remanufacturing outsourcing operations: (1) outsourcing remanufacturing to a 3PR (Model T) or (2) outsourcing the remanufacturing to its retailer (Model R). Several key findings related to these models are summarized as the following. (1) Compared with Model R, there was a higher quantity of both products in Model T. (2) Compared with Model R, outsourcing the remanufacturing operations to the 3PR was usually beneficial for the OEM and the entire supply chain but always detrimental to the retailer. (3) Compared with Model R, outsourcing the remanufacturing to the TPR was always detrimental to our environment than the strategy of outsourcing it to the retailer.

Based on the above results, we concluded that if the OEMs cared about economic performance, outsourcing the remanufacturing operations to the 3PR was a practical strategy. On the other hand, if they cared about environmental performance, outsourcing the retailer's remanufacturing operations was a preferred strategy.

This research could be extended in the following directions. First, we assumed that the OEM was limited to a linear wholesale price. Although this is standard in the literature, it is also important to understand encroachment implications when an OEM uses a more complex pricing mechanism. Second, we assumed that the costs, emissions, and consumer preferences related to remanufacturing were the same for retailers and third parties so that future research can generalize the model to different costs and emissions for third parties and retailers. Consumers may exhibit different preferences over the remanufactured products provided by different remanufacturers. We hope this research will open other potentially interesting avenues of research. Finally, given our focus on sustainability issues, we removed other factors, which included the strategic choice of leasing and selling, which can potentially play an important role in remanufacturing with durables.

Appendix A

We get $\frac{\theta(2\theta+3c_n-2-\theta c_n)}{\theta+1} < c_r < \theta c_n$ by solving $q_n^{C*} > q_r^{C*} > 0$ and $\frac{\theta^2 c_n - \theta c_n + 2\theta^2 - 2c_n - 4\theta + 2}{3\theta - 5} < c < \theta c_n$ by solving $q_n^{N*} > q_r^{N*} > 0$. Setting $c_{r1} = \frac{\theta(2\theta+3c_n-2-\theta c_n)}{\theta+1}$ and $c_{r2} = \frac{\theta^2 c_n - \theta c_n + 2\theta^2 - 2c_n - 4\theta + 2}{3\theta - 5}$, we obtain $c_{r2} < c_{r1}$ if $0 < \theta < 593/2705$, and $c_{r1} < c_{r2}$ if $593/2705 < \theta < 1$.

Appendix B

Based on the Stackelberg game, the manufacturer, as a leader, first determined the optimal price w^* and p_n^* anticipated how the remanufacturer would respond after it has observed the OEM decisions. As a follower, the remanufacturer observed this and chose the optimal wholesale price as a response. The model was solved by backward induction.

In the first stage, for the given prices of the OEM, the remanufacturer solved the following problem:

$\pi_R = (p_r - w - c_r)q_r = \frac{(p_r - w - c_r)(\theta p_n - p_r)}{\theta}$. The first derivative $\frac{\partial \pi_R}{\partial p_r} = \frac{\theta p_n - 2p_r + w + c_r}{\theta}$ and solving it yielded $p_r^{N*}(w, p_n) = \frac{\theta p_n + w + c_r}{2}$. Substituting p_r^{N*} into demand functions yielded $q_n^{C*}(w, p_n) = \frac{2(1-\theta)(2-\theta)p_n + w + c_r}{\theta}$ and $q_r^{N*}(w, p_n) = \frac{\theta p_n - w - c_r}{\theta}$. Substituting q_n^{C*} and q_r^{N*} into OEM's profit function yielded $\pi_M^{N*} = \frac{w(\theta p_n - w - c_r)}{\theta} + (p_n - c_n)\left(1 - \frac{(2-\theta)p_n - w - c_r}{\theta}\right)$. Then, we obtained $\frac{\partial \pi_M}{\partial w} = \frac{2\theta p_n - 2w - c_r - \theta c_n}{\theta}$ and

$\frac{\partial \pi_M}{\partial p_n} = \frac{2W + 2(1-\theta) - (4-2\theta)p_n + (2-\theta)c_n + c_r}{2(1-\theta)}$. Jointly solving these two equations yielded $p_n^{C*} = (1 + c_n)/2$ and $w^* = (\theta - c_r)/2$.

Appendix C

Based on the Stackelberg game, the OEM, as a leader, first determined the optimal price p_n in anticipating how the remanufacturer would respond after observing the OEM decisions. The remanufacturer, as a follower, observed this and chose the optimal wholesale price as a response. The model was solved by backward induction.

In the first stage, for the given prices of the OEM, the remanufacturer solved the following problem:

$\pi_R = (p_r - c_r)q_r = ((p_r - c_r)(\theta p_n - p_r))/(\theta(1 - \theta))$. The partial derivative to p_r is $\frac{\partial \pi_R}{\partial p_r} = \frac{\theta p_n - 2p_r + c_r}{\theta(1 - \theta)}$. Solving this equation yielded $p_r^{N*}(w, p_n) = \frac{\theta p_n + c_r}{2}$. Substituting p_r^{N*} into demand functions of Model N respectively yielded $q_n^{N*}(p_n) = (2(1 - \theta) - (2 - \theta)p_n + c_r)/(2(1 - \theta))$ and $q_r^{N*}(p_n) = (\theta p_n - c_r)/(\theta(1 - \theta))$. Substituting q_n^{N*} and q_r^{N*} into manufacturer's profit function yielded $\pi_M = (p_n - c_n)(1 - \frac{(2-\theta)p_n - c_r}{2(1-\theta)})$. The partial derivative to p_n is $\frac{\partial \pi_M}{\partial p_n} = \frac{2(1-\theta) + (2-\theta)c_n + c_r}{2(1-\theta)}$. Solving it yielded $p_n^{N*} = \frac{2(1-\theta) + (2-\theta)c_n + c_r}{2(1-\theta)}$. Substituting p_n^{N*} into the demand function yielded $p_r^{N*} = \frac{2\theta(1-\theta) + \theta c_n + \theta(2-\theta)c_n + (4-\theta)c_r}{4(1-\theta)}$.

Appendix D

Because $p_n^{N*} = \frac{(1+c_n)}{2}$, $p_n^{N*} = (2(1-\theta) + (2-\theta)c_n + c_r)/(\theta(2-\theta))$, then $p_n^{C*} - p_n^{N*} = \frac{(1-\theta-c_r)}{2(1-\theta)}$. Because of $c_r < \theta c_n$, $c_n < 1$, so $c_r < \theta$. Thus, we obtained $p_n^{C*} > p_n^{N*}$.

Appendix E

We obtained this proposition from $\pi_M^{C*} - \pi_M^{N*} = \frac{(1-\theta-c_r)^2}{4(1-\theta)}$, and it was obviously positive because $0 < \theta < 1$, i.e. $\pi_M^{C*} > \pi_M^{N*}$.

Appendix F

We obtained that the remanufacturer's optimal profit in Model C was $\frac{(\theta c_n - c_r)^2}{16\theta(1-\theta)}$; the optimal profit of the remanufacturer in the competitive model was $\frac{(2\theta - 2\theta^2 + 3\theta c_r + 2\theta c_n - c_n\theta^2 - 4c_r)^2}{16\theta(1-\theta)(2-\theta)^2}$. Comparing the former with the latter, we found that $\pi_R^{C*} - \pi_R^{N*} = c_n\theta^3 + \theta^3 - \theta^2 - 2\theta^2 c_n - 3c_r\theta^2 - c_r c_n\theta^2 + 2c_r c_n\theta + \frac{2\theta c_r^2 + 4\theta c_r - 3c_r^2}{(4\theta(2-\theta)^2)}$.

Setting $c_{r3} = (\theta(\theta c_n - 2c_n + \theta - 1))/(2\theta - 3)$, we observed that if $\max(c_{r1}, c_{r2}) < c_r < c_{r3}$, $\pi_R^{C*} < \pi_R^{N*}$, then $c_{r3} < c_r < \theta c_n$, $\pi_R^{C*} > \pi_R^{N*}$.

Appendix G

We only analyzed the disposal impact of the per-unit product, and we defined it as $e_n = i_n(q_n - q_r)$ because the clearance impact was removed by remanufacturing. Similarly, the clearance impact of a remanufactured product was $e_r = i_r q_r$. Then, the disposal impact in Model C and Model N were $E^C = i_n(q_n^{C*} - q_r^{C*}) + i_u q_r^{C*} = i_n q_n^{C*} + (i_n - i_u)q_r^{C*}$ and $E^N = i_n(q_n^{N*} - q_r^{N*}) + i_u q_r^{N*} = i_n q_n^{N*} + (i_n - i_u)q_r^{N*}$, respectively.

We can get $E^C - E^N = \frac{1}{2(\theta - c_r)(\theta - 2)\theta}$. The c_r is smaller than θ because $c_r < \theta c_n$ and θ is within $[0,1]$. So, it is easy to know $E^C - E^N$ is always negative.

Appendix H

The optimal total profit in Model C was $\pi_T^C = \pi_M^C + \pi_R^C$; the optimal total profit in Model N was $\pi_T^N = \pi_M^N + \pi_R^N$. Substituting the optimal profit solutions of the manufacturer and the remanufacturer into these equations, we obtained $\pi_T^C = \frac{c_n^2}{16} - \frac{c_n}{2} - \frac{3(c_n - c_r)^2}{16(\theta - 1)} + \frac{3c_r^2}{16\theta} + \frac{1}{4}$,

$\pi_T^N = \frac{c_r - 2c_n - 2\theta + \theta c_n + 2}{8(\theta - 1)(\theta - 2)} - (4c_r - 2\theta - 2\theta c_n - 3\theta c_r + \theta 2c_n + \frac{2\theta^2}{(16\theta(\theta - 1)(\theta - 2)^2)})$. Comparing the former with the latter, we have $\pi_T^C - \pi_T^N = \frac{(\theta - c_r)(c_r + \theta - 2\theta c_n - \theta c_r + \theta^2 c_n)}{4\theta(2 - \theta)^2}$. We found $\pi_T^C - \pi_T^N > 0$ in $\max(c_{r1}, c_{r2}) < c_r < \theta c_n$.

Appendix I

That is, $\pi_R^N < \pi_R^C + \rho_1(\pi_M^C - \pi_M^N)$. Solving this equation after substituting the profits' equilibrium outcomes into this equation, we found that only when the paying ratio was not smaller than $\phi_1 = \frac{2\theta c_r - 2c_r - c_n\theta^2 - \theta^2 + 2\theta c_n + \theta}{(\theta - c_r)(2 - \theta)}$, the profits of the manufacturer and the remanufacturer in Model C were higher than those in Model N.

References

- Abbey, J. D., Meloy, M. G., Blackburn, J., & Guide, V. D. R. (2015). Consumer markets for remanufactured and refurbished products. *California Management Review*, 57 (4), 26-42. <https://doi.org/10.1525/cmr.2015.57.4.26>
- Abdulrahman, M. D. A., Subramanian, N., Liu, C., & Shu, C. Viability of remanufacturing practice: A strategic decision making framework for Chinese auto-parts companies. *Journal of Cleaner Production*, 105, 311-323. <https://doi.org/10.1016/j.jclepro.2014.02.065>
- Agrawal, V. V., Atasu, A., & Van Ittersum, K. (2015). Remanufacturing, third-party competition, and consumers' perceived value of new products. *Management Science*, 61 (1), 60-72. <https://doi.org/10.1287/mnsc.2014.2099>
- Arora, A., Fosfuri, A., & Rønde, T. (2013). Managing licensing in a market for technology. *Management Science*, 59 (5), 1092-1106. <https://doi.org/10.1287/mnsc.1120.1628>
- Atasu, A., Sarvary, M., & Van Wassenhove, L. N. (2008). Remanufacturing as a marketing strategy. *Management Science*, 54 (10), 1731-1746. <https://doi.org/10.1287/mnsc.1080.0893>
- Atasu, A., Toktay, L. B., & Van Wassenhove, L. N. (2013). How collection cost structure drives a manufacturer's reverse channel choice. *Production & Operations Management*, 22 (5), 1089-1102. <https://doi.org/10.1111/j.1937-5956.2012.01426.x>
- Bacik, R., Fedorko, R., Nastisin, L., & Gavurova, B. (2018). Factors of communication mix on social media and their role in forming customer experience and brand image. *Management & Marketing*, 13(3), 1108-1118. <https://doi.org/10.2478/mmcks-2018-0026>
- Big players emerge in fragmented brokerage market. (2021, January 8) https://www.cbronline.com/news/big_players_emerge_in_fragmented_brokerage_market/
- Cerda, C. (2011). Willingness to pay to protect environmental services: a case study with use and non use values in central Chile. *Interciencia*, 36 (11), 796-802. <https://doi.org/10.3390/su12030891>
- Chen, Y., Li, B., Zhang, G., & Bai, Q. (2020). Quantity and collection decisions of the remanufacturing enterprise under both the take-back and carbon emission capacity regulations. *Transportation Research Part E-logistics and Transportation Review*, 141. <https://doi.org/10.1016/j.tre.2020.102032>

- Chen, Y., Wang, J., Yu, Y. (2019). A Study on consumers' willingness to pay for remanufactured products: A study based on hierarchical regression method. *Frontiers in Psychology*, 10. <https://doi.org/10.3389/fpsyg.2019.02044>
- Dai, L., Shu, T., Chen, S., Wang, S., & Lai, K. K. (2020). CSR remanufacturing supply chains under WTP differentiation. *Sustainability*, 12 (6). <https://doi.org/10.3390/su12062197>
- Debo, L. G., Toktay, L. B., & Van Wassenhove, L. N. (2005). Market segmentation and product technology selection for remanufacturable products. *Management Science*, 51 (8), 1193-1205. <https://doi.org/10.1287/mnsc.1050.0369>
- Dvorsky, J., Petrakova, Z., Khan, K. A., Formanek, I., & Mikolas, Z. (2020). Selected aspects of strategic management in the service sector. *Journal of Tourism and Services*, 11 (20), 109-123. <https://doi.org/10.29036/jots.v11i20.146>
- Esenduran, G., Kemahlioglu-Ziya, E., & Swaminathan, J. M. (2016). Take-back legislation: Consequences for remanufacturing and environment. *Decision Sciences*, 47 (2), 219-256. <https://doi.org/10.1111/deci.12174>
- Fang, C., You, Z., Yang, Y., Chen, D., & Mukhopadhyay, S. (2019). Is third-party remanufacturing necessarily harmful to the original equipment manufacturer? *Annals of Operations Research*, 291 (1-2), 317-338. <https://doi.org/10.1007/s10479-019-03445-2>
- Fedorko, I., Bacik, R., & Gavurova, B. (2018). Technology acceptance model in e-commerce segment. *Management & Marketing Challenges for the Knowledge Society*, 13(4), 1242-1256. <https://doi.org/10.2478/mmcks-2018-0034>
- Ferguson, M. (2010). Strategic issues in closed-loop supply chains with remanufacturing. In Ferguson, M., Souza, G. C. (Eds.), *Closed-Loop Supply Chains: New Developments to Improve the Sustainability of Business Practices* (pp. 9-21). Taylor and Francis.
- Ferguson, M. E., & Toktay, L. B. (2006). The effect of competition on recovery strategies. *Production and Operations Management*, 15 (3), 351-368. <https://doi.org/10.1111/j.1937-5956.2006.tb00250.x>
- Ferguson, M. E., & Toktay, L. B. (2006). The effect of competition on recovery strategies. *Production & Operations Management*, 15 (3), 351-368. <https://doi.org/10.1111/j.1937-5956.2006.tb00250.x>
- Ferrer, G., & Swaminathan, J. M. (2006). Managing new and remanufactured products. *Management Science*, 52 (1), 15-26. <https://doi.org/10.1287/mnsc.1050.0465>
- Ferrer, G., & Swaminathan, J. M. (2010). Managing new and differentiated remanufactured products. *European Journal of Operational Research*, 203 (2), 370-379. <https://doi.org/10.1016/j.ejor.2009.08.007>
- Gavurova, B., Bacik, R., Fedorko, R., & Rigelsky, M. (2018). Analytical view of online marketing tools in the dimension of marketing campaigns' personalization in Slovakia. *Маркетинг і менеджмент інновацій*, (2), 186-200. <https://doi.org/10.21272/mmi.2018.2-15>
- Georgiandis, P., & Vlachos, D. (2004). The effect of environmental parameters on product recovery. *European Journal of Operational Research*, 157 (2), 449-464. [https://doi.org/10.1016/S0377-2217\(03\)00203-0](https://doi.org/10.1016/S0377-2217(03)00203-0)
- Geyer, R., Van Wassenhove, L. N., & Atasu, A. (2007). The economics of remanufacturing under limited component durability and finite product life cycles. *Management Science*, 53 (1), 88-100. <https://doi.org/10.1287/mnsc.1060.0600>
- Giutini, R., & Gaudette, K. (2003). Remanufacturing: The next great opportunity for boosting U.S. productivity. *Business Horizons*, 46 (6), 41-48. [https://doi.org/10.1016/S0007-6813\(03\)00087-9](https://doi.org/10.1016/S0007-6813(03)00087-9)
- Golinska, P. (2014). The lean approach for improvement of the sustainability of a remanufacturing process. *Logforum*, 10 (3), 285-293.
- Guide, V. D. R. Jr., & Li, J. (2010). The potential for cannibalization of new products sales by remanufactured products. *Decision Sciences*, 41 (3), 547-572. <https://doi.org/10.1111/j.1540-5915.2010.00280.x>
- Hauser, W. M., & Lund, R. T. (2003) *The Remanufacturing Industry: Anatomy of a Giant: a View of Remanufacturing in America Based on a Comprehensive Survey across the Industry*. Dept. of Manufacturing Engineering, Boston University.
- Horvath, J., Gavurova, B., Bacik, R. & Fedorko, R. (2021). Identification of Uncertainty Factors in the Consumer Behaviour of the New Generation of Customers at the E-commerce Level. *Journal of Tourism and Services*, 22(12), 168-183. <https://doi.org/10.29036/jots.v12i22.263>
- ISO 14040. Environmental management - life cycle assessment - principles and framework. *International Standard Organization (ISO) 2006*, Geneva, Switzerland.

ISO 14044. Environmental management - life cycle assessment - requirement and guidelines. *International Standard Organization (ISO) 2006*, Geneva, Switzerland.

Karakayali, I., Emir-Farinas, H., & Akcali, E. (2007). An analysis of decentralized collection and processing of end-of-life products. *Journal of Operations Management*, 25 (6), 1161-1183. <https://doi.org/10.1016/j.jom.2007.01.017>

Kasych, A. O., Vochozka, M., & Yakovenko, Y. (2019). Diagnostics of the stability states of enterprises and the limits of their tolerance. *Quality - Access to Success*, 20 (172), 3-12.

Lee, C., Realf, M., & Ammons, J. (2011). Integration of channel decisions in a decentralized reverse production system with retailer collection under deterministic non-stationary demands. *Advanced Engineering Informatics*, 25 (1), 88-102. <https://doi.org/10.1016/j.aei.2010.04.001>

Li, X., Li, Y., & Saghaian, S. (2013). A Hybrid manufacturing/remanufacturing system with random remanufacturing yield and market-driven product acquisition. *IEEE Transactions on Engineering Management*, 60 (2), 424-437. <https://doi.org/10.1109/TEM.2012.2215873>

Liu, Z., Tang, J., Li, B. Y., Wang, Z. (2017). Trade-off between remanufacturing and recycling of WEEE and the environmental implication under the Chinese Fund Policy. *Journal of Cleaner Production*, 167, 97-109. <https://doi.org/10.1016/j.jclepro.2017.08.137>

Majumder, P., & Groenevelt, H. (2001). Competition in remanufacturing. *Production and Operations Management*, 10 (2), 125-141. <https://doi.org/10.1111/j.1937-5956.2001.tb00074.x>

Mezulanik, J., Durda, L., Civelek, M., & Malec, L. (2020). Ride-hailing vs. taxi services: A survey-based comparison. *Journal of Tourism and Services*, 11 (20), 170-186. <https://doi.org/10.29036/jots.v11i20.155>

Michaud, C., & Llerena, D. (2011). Green consumer behaviour: an experimental analysis of willingness to pay for remanufactured products. *Business Strategy and the Environment*, 20 (6), 408-420. <https://doi.org/10.1002/bse.703>

Mitra, S., & Webster, S. (2008). Competition in remanufacturing and the effects of government subsidies. *International Journal of Production Economics*, 111 (2), 287-298. <https://doi.org/10.1016/j.ijpe.2007.02.042>

National Development and Reform Commission. (2022, August 31). *The administrative measures for pilot remanufacturing of automobile parts & accessories (in Chinese)*, Development and Reform Office Huanzi [2008] No. 523 March 2, 2008. <https://en.ndrc.gov.cn/>

Oraiopoulos, N., Ferguson, M. E., & Toktay, L. B. (2012). Relicensing as a secondary market strategy. *Management Science*, 58 (5), 1022-1037. <https://doi.org/10.1287/mnsc.1110.1456>

Ovchinnikov, A. (2011). Revenue and cost management for remanufactured products. *Production and Operations management*, 20 (6), 824-840. <https://doi.org/10.1111/j.1937-5956.2010.01214.x>

Petit-Boix, A., Llorach-Massana, P., Sanjuan-Delmás, D., Sierra-Pérez, J., Vinyes, E., Gabarrell, X., Rieradevall, J., & Sanyé-Mengual, E. (2017). Application of life cycle thinking towards sustainable cities: A review. *Journal of Cleaner Production*, 166, 939-951. <https://doi.org/10.1016/j.jclepro.2017.08.030>

Pimonenko, T., Bilan, Y., Horak, J., Starchenko, L., & Gajda, W. (2020). Green brand of companies and greenwashing under sustainable development goals. *Sustainability*, 12 (4). <https://doi.org/10.3390/su12041679>

Radavičius, T., van der Heide, A., Palitzsch, W., Rommens, T., Denafas, J., & Tvaronavičienė, M. (2021). Circular solar industry supply chain through product technological design changes. *Insights into Regional Development*, 3(3), 10-30. [https://doi.org/10.9770/IRD.2021.3.3\(1\)](https://doi.org/10.9770/IRD.2021.3.3(1))

Razu, G., Ovchinnikov, A., & Blass, V. (2017). Economic, environmental, and social impact of remanufacturing in a competitive setting. *IEEE Transactions on Engineering Management*, 64 (4), 476-490. <https://doi.org/10.1109/TEM.2017.2714698>

Savaskan, R. C., Bhattacharya, S., & Van Wassenhove, L. N. (2004). Closed-loop supply chain models with product remanufacturing. *Management Science*, 50 (2), 239-252. <https://doi.org/10.1287/mnsc.1030.0186>

Shi, W., & Min, K. J. (2014). Product remanufacturing: A real options approach. *IEEE Transactions on Engineering Management*, 61 (2), 237-250. <https://doi.org/10.1109/TEM.2013.2278533>

Shu, T., Liao, H., Chen, S., Wang, S., Lai, K. K., & Gan, L. (2016). Analysing remanufacturing decisions of supply chain members in uncertainty of consumer preferences. *Applied Economics*, 48 (34), 3208-3227. <https://doi.org/10.1080/00036846.2015.1136400>

- Shulman, J. D., Coughlan, A. T., & Savaskan, R. C. (2010). Optimal reverse channel structure for consumer product returns. *Marketing Science*, 29 (6), 1071-1085. <https://doi.org/10.1287/mksc.1100.0578>
- Strakova, J., Koraus, A., Vachal, J., Pollak F., Cernak, F., Talir, M. & Kollmann, J. (2021a). Sustainable Development Economics of Enterprises in the Services Sector Based on Effective Management of Value Streams. *Sustainability*, 13 (16). <https://doi.org/10.3390/su13168978>
- Strakova, J., Partlova, P., Dobrovic, J. & Vachal, J. (2018). Situational analysis and its role in the process of strategic business management. *Polish Journal of Management Studies*, 18 (1), 353-364. <https://doi.org/10.17512/pjms.2018.18.1.26>
- Strakova, J., Rajiani, I., Partlova, P., Vachal, J., & Dobrovic, J. (2020). Use of the Value Chain in the Process of Generating a Sustainable Business Strategy on the Example of Manufacturing and Industrial Enterprises in the Czech Republic. *Sustainability*, 12 (4), 1520. <https://doi.org/10.3390/su12041520>
- Strakova, J., Talir, M., Kollmann, J., Partlova, P. & Vachal, J. (2021b). An integrated model of corporate environment, including value chain, as a competitiveness tool for small and medium enterprises. *Polish Journal of Management Studies*, 23 (1), 370-384. <https://doi.org/10.17512/pjms.2021.23.1.23>
- Suhariyanto, T. T., Wahab, D. A., & Rahman, M. N. A. (2017). Multi-life cycle assessment for sustainable products: A systematic review. *Journal of Cleaner Production*, 165, 677-696. <https://doi.org/10.1016/j.jclepro.2017.07.123>
- The Brands of the Future Must Be Sustainable. (2021, January 8). <https://popsop.com/2012/12/the-brands-of-the-future-must-be-sustainable/>
- Vrbka, J., & Rowland, Z. (2020). *Using artificial intelligence in company management*. In Kacprzyk, J. (Ed.), *Lecture Notes in Networks and Systems*, (pp. 422-429), Switzerland. Springer Nature. https://doi.org/10.1007/978-3-030-27015-5_51
- White, A. L., Stoughton, M., & Feng, L. (1999). *Servicizing: The quiet transition to extended producer responsibility*. U.S. Environmental Protection Agency, Office of Solid Waste. <https://www.epa.gov/environmental-topics/land-waste-and-cleanup-topics>
- Wu, X., & Zhou, Y. (2016). Does the entry of third-party remanufacturers always hurt original equipment manufacturers? *Decision Sciences*, 47 (4), 762-780. <https://doi.org/10.1111/deci.12194>
- Xiong, Y., Zhou, Y., Li, G., Chan, H. K., & Xiong, Z. (2013). Don't forget your supplier when remanufacturing. *European Journal of Operational Research*, 230 (1), 15-25. <https://doi.org/10.1016/j.ejor.2013.03.034>
- Yan, W., Xiong, Y., Xiong, Z., & Guo, N. (2015). Bricks vs. clicks: Which is better for marketing remanufactured products? *European Journal of Operational Research*, 242 (2), 434-444. <https://doi.org/10.1016/j.ejor.2014.10.023>
- Zhu, X. (2016). Managing the risks of outsourcing: Time, quality and correlated costs. *Transportation Research Part E: Logistics and Transportation Review*, 90, 121-133. <https://doi.org/10.1016/j.tre.2015.06.005>
- Zikopoulos, C., & Tagaras, G. (2007). Impact of uncertainty in the quality of returns on the profitability of a single-period refurbishing operation. *European Journal of Operational Research*, 182 (1), 205-225. <https://doi.org/10.1016/j.ejor.2006.10.025>
- Zou, Z. B., Wang, J. J., Deng, G. S., & Chen, H. (2016). Third-party remanufacturing mode selection: Outsourcing or authorization? *Transportation Research Part E: Logistics and Transportation Review*, 87, 1–19. <https://doi.org/10.1016/j.tre.2015.12.008>

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