GAME THEORETICAL ANALYSIS OF REMANUFACTURING QUALITY AND CAPACITY CHOICE

CHENG-HAN WU

Department of Industrial and Information Management, National Cheng-Kung University, Taiwan
E-mail: wuchan@mail.ncku.edu.tw

Abstract - Remanufacturing capacities are constrained by the collected amount of end-of-life (EOL) products resulting in the make-from-stock model for remanufacturing industries. Remanufacturers may select quality choices in a strategic manner to improve their remanufacturing capacities. Thus, we examine a Cournot duopoly where an original equipment manufacturer (OEM) sells new products and an independent remanufacturer (IR) remanufactures EOL products and determine the production quantities of low- and high-quality remanufactured products. The IR can select pure low-quality, pure high-quality, or mixed-quality policies. We formulate the dynamics between the OEM and IR in a two-period game, solve for the firms' equilibrium quantities through dynamic programming, and derive the conditions of the production-quality policies.

Keywords - Quality; Remanufacturing; Cournot Game; Production-Quality Policy; Make From Stock

I. INTRODUCTION

Consumers desire low-priced functional products, and increased environmental awareness has accelerated the development of the remanufacturing industry. Remanufacturing is a process for restoring end-of-life (EOL) products produced by original equipment manufacturers (OEMs) to near-new conditions through replacement and rebuilding processes. Thus, the reduction in raw materials required and production procedures allow many remanufactured products to have smaller environmental footprints and lower production costs than new products. For example, Satyam (2017) found that the automotive parts remanufacturing market is anticipated to hit US $58.8 billion at a compound annual growth rate of 6.6% between 2017 and 2025.

Many empirical studies (e.g., D'Souza et al., 2007; Subramanian and Subramanyam, 2012; Abbey et al., 2015; Joshi and Rahman, 2015) have found that both sales prices and consumer quality perception are significant factors affecting the purchasing of remanufactured products. Specifically, Subramanian and Subramanyam (2012), Abbey et al. (2015), and Parker et al. (2015) found that consumers generally assign lower reservation prices to remanufactured products than to new products because of uncertainty regarding quality even when controlling for warranty length. Abbey et al. (2015) indicated that remanufactured products currently only account for approximately 5-10 % of the consumer market because their sales are hindered by a lower quality perception. In this regard, quality in remanufacturing is a significant issue in practice and for research.

Because remanufacturing follows a "make from stock" model (Fleischmann et al., 2004; Galbreth and Blackburn, 2006), the remanufacturing capacity is associated with the amount of EOL products and the desired quality level after remanufacturing (Ferguson et al., 2009). Specifically, remanufacturers sort EOL products in variable conditions before the restoration process, after which they determine which products should be remanufactured and which should be scrapped based on their desired quality levels (Galbreth and Blackburn, 2006, 2010; Wei et al., 2015). Therefore, when a remanufacturer selects a higher quality level, fewer EOL products qualify for remanufacture, and the remanufacturing capacity decreases. In contrast, reducing the quality level for a greater remanufacturing capacity intensifies competition between remanufacturers and OEMs, hurting profits but potentially benefiting consumers because of lower prices (Melumad and Ziv, 2004). As a result, remanufacturers face a dilemma when determining their production quantities and quality levels.

Many researchers have provided thorough literature reviews on remanufacturing in the fields of revenue management and management science (Ilgin and Gupta, 2010; Souza, 2012; Steeneck and Sarin, 2013; Govindan et al., 2015; Wei et al., 2015; Kurilova-Palisaitiene et al., 2018). Majumder and Groenevelt (2001) examined pricing decisions in a duopolistic competition between an OEM and local IR under a two-period static model and investigated different configurations of reverse logistics for collecting used products.

Debo et al. (2005) considered a monopolistic model under a two-period dynamic setting in which an OEM determines whether to sell remanufactured products and determines the level of remanufacturing associated with the return rate and product technology. Ferguson and Toktay (2006) also considered a two-period static model in which an OEM competes with a local IR and makes its recovery decisions to deter the entry of the IR. Atasu et al. (2008) incorporated the effects of product-life-cycle and different consumer types into both monopolistic and duopolistic models in a CLSC and proposed that a two-period static setting is sufficient

for obtaining managerial insights while maintaining analytical tractability. De Giovanni and Zaccour (2014) discussed the collection strategy of an IR who determines whether to exclusively undertake the reverse logistic or outsource it to either a retailer or third-party collector under a two-period dynamic setting and compared the IR's performances between decentralized and centralized CLSCs. Moreover, De Giovanni and Zaccour (2014) proposed that the return rate captures the dynamic nature and is more appropriate for considering the dynamic setting in their two-period CLSC model.

However, these studies overlook the relationship between production decisions and quality policies. This paper bridges this gap by associating an IR's production capacity with its quality policies and then investigates the IR's quality policies and the firms' production decisions in quality competition under a two-period dynamic setting.

The availability of EOL products is critical to the capacities of remanufacturers (Global Industry Analysts, Inc., 2015) and thus affects IR decisions and interactions with OEMs. For example, Ferguson and Toktay (2006) found that an OEM can choose to collect EOL products to deter the entry of an IR such that the capacity and profitability of IRs are limited. Consequently, IRs are likely to be more aggressive when collecting EOL products in recycled markets. Heese et al. (2005) considered that an OEM adopts a take-back strategy as a deterrent to prevent IRs from selecting their profitable strategies.

These researchers discussed OEMs' take-back behaviour under different competitive environments. Teunter and Flapper (2011) examined the optimal acquisition and remanufacturing policies regarding the sorting problem of collected cores for remanufacturing between an IR and third-party collectors in a centralized system. Wu (2015) further extended previous works by considering a duopolistic supply chain in which both price competition in a sales market and incentive competition in a recycled market have emerged; then, Wu discussed the firms' sales and collection decisions and an IR's collection strategy in a deterministic model. In these works, the IRs aim to increase the availability of EOL products to increase their remanufacturing capacities such that remanufacturing economies of scales can be achieved. In this study, we further incorporate the interdependency between remanufacturing capacity and the quality policy chosen by the IR. Furthermore, we investigate the effect of the IR's quality policy on profits, consumer surplus, and social welfare.

Therefore, in this study, we examine whether an independent remanufacturer (IR) can control the average quality level of its remanufactured products by allocating production capacities between low- and high-quality products. Such investigations are interesting and provide insights into firms' profitability, consumer surplus, and social welfare under competition between an OEM and an IR in a two-period dynamic model that considers the capacity and quality policies of the IR.

II. MODEL FORMULATION

2.1. Quality Choice

Consider a two-period supply chain model consisting of an OEM, denoted by o, and an IR, denoted by r. In the first period, the OEM sells new products in a monopoly. In the second period, the IR recovers EOL products that were sold by the OEM in the first period and sells them as remanufactured products. Because the new and remanufactured products are substitutable for consumers, the firms compete in a duopolistic Cournot game in the second period.

In the market, consumers make purchasing choices depending on their utilities, which are associated with the firms' sales prices and average quality levels. We consider two possible quality levels for remanufactured products, namely, high (h) and low (l).A high-quality remanufactured product requires more EOL products to obtain a qualified core and thus consumes more collected quantities for remanufacturing than low-quality remanufactured products. Because the IR's production is limited by the collection of EOL products, the IR may reduce the average quality level of remanufactured products to increase total production. Consistent with Melumad and Ziv (2004), we consider the quality levels of the low- and high-quality products to be 0 and 1, respectively. Thus, the average quality of remanufactured products can be designed as $\chi_r = q_{rh}/(q_{rl} + q_{rh}), 0 \le \chi_r \le 1$. This formulation indicates that consumers perceive the average quality of remanufactured products to be higher when the IR selects a larger amount of high-quality remanufactured products. Therefore, the IR can control the average quality of remanufactured products by allocating production quantities between low- and high-quality products.

The decision process is as follows. In the first period, the OEM determines the sales quantity q_1 based on its anticipation of the IR's quality choice; in the second period, the OEM determines the sales quantity q_o and the IR determines the sales quantities, q_{rl} and q_{rh}, of the low- and high-quality remanufactured products, respectively. The IR has three quality policies, i.e., H, L, and C, indicating that it produces pure high-quality products (i.e., $q_{rl} = 0$ and $q_{rh} > 0$), pure low-quality products (i.e., $q_{rl} > 0$ and $q_{rh} = 0$), and both low- and high-quality products (i.e., $q_{rl} >$ and $q_{rh} > 0$), respectively. Moreover, because the IR collects EOL products for remanufacturing, two possible statuses exisst for remanufacturing capacity. Specifically, status U indicates that the IR's remanufacturing

capacity is ample and thus that the IR can choose a quantity at an economy of scale. However, status B indicates that the IR's remanufacturing capacity is limited, and the IR's quantity decision is therefore contingent on the collected quantity. Throughout the paper, we use subscripts $i \in \{o, r\}$ to denote the firms.

2.2. Demand Functions

Consumers make their purchasing choices based on the utilities of both firms' products. To capture heterogeneity in consumer preferences, we assume that consumers' reservation price, denoted by θ, is uniformly distributed between 0 and 1 (i.e., $f(\theta) \sim \text{Uniform}[0,1]$) (Atasu et al., 2008; Cattani et al., 2006; Ferguson and Toktay, 2006; Wu, 2012). In the first period, a type-θ consumer receives utility $U_1 = \theta - p_1 + \alpha \chi_o$ from the new product sold by the OEM, where p_1 denotes the sales price of the OEM in the first period, $0 \le \chi_o \le 1$ denotes the average quality level of new products, and α is a scaling factor for consumer sensitivity with respect to the average quality level (i.e., a higher value for α indicates that consumers are more sensitive to the average quality level). We can derive the new product demand in the first period, as follows: $q_1 = \int_{\theta \in \{\theta_1 : U_1 \ge 0\}} f(\theta)\, \mathrm{d}\theta = 1 - p_1 + \alpha \chi_o$; thus, the inverse demand function is obtained: $p_1 = 1 - q_1 + \alpha \chi_o$.

In the second period, a consumer receives a utility $U_o = \theta - p_o + \alpha \chi_o$ from a new product and $U_r = \rho\theta - p_r + \alpha \chi_r$ from a remanufactured product, where $0 < \rho < 1$ represents the discount factor of the reservation price for the remanufactured products compared to the new products; i.e., as ρ approaches one, consumers have the same reservation price for the remanufactured and new products. The demands of the products can be calculated as follows:

$$q_o = \int_{\theta \in \{\theta_o : U_o \ge \max\{U_r, 0\}\}} f(\theta)\, \mathrm{d}\theta = \frac{-\alpha\chi_o + p_o - p_r + \rho + \alpha\chi_r - 1}{\rho - 1},$$

$$q_r = \int_{\theta \in \{\theta_r : U_r \ge \max\{U_o, 0\}\}} f(\theta)\, \mathrm{d}\theta = \frac{\alpha\rho\chi_o - \rho p_o + p_r - \alpha\chi_r}{(\rho - 1)\rho}.$$

The total market demand $q_o + q_r$ is not constant; instead, it is dependent on the IR's price and average quality level. Without loss of generality, the average quality level of new products is normalized to 1, i.e., $\chi_o = 1$. To focus on the duopolistic model, we consider that $\rho - (1 + \alpha - c)/(q_{rh} + q_{rl}) \le 0$ for $q_o \ge 0$. This assumption of ρ indicates that the consumer reservation price for remanufactured products is not overly high, and the market therefore remains profitable to the OEM.

We then substitute the forms of χ_i into the demand functions q_o and q_r, and after some arrangement, we obtain the inverse demand functions as follows:

$p_o = 1 + \alpha - q_o - \rho(q_{rh} + q_{rl})$ and $p_r = \rho(1 - (q_o + q_{rh})) + \alpha q_{rh}/(q_{rh} + q_{rl}) - \rho q_{rl}$.

2.3. Firm Objectives and Equilibrium Decisions

We now formulate the firms' profit functions. In the first period, the OEM selects the sales quantity in a monopoly, and in the second period, the OEM and IR determine their sales quantities simultaneously. We formulate the OEM's problem as a two-period model. Through backward induction, we first solve the firms' problems in the second period. Specifically, the OEM's second-period objective is

$$\max_{q_o \ge 0} \quad \pi_o = (p_o - c) q_o, \tag{2}$$

where c is the unit production cost for a new product. Regarding the IR's problem, the IR's total production is limited by the collection of the EOL products at the end of the first period. We assume that only a proportion of the EOL products, denoted by γ, can be collected at the beginning of the second period; i.e., the γq_1 of the EOL products can be collected at the beginning of the second period; i.e., a γq_1 high-quality unit requires more EOL products to obtain a qualified core.

Thus, the consumption rate of a high-quality unit, denoted by κ, is greater than that of a low-quality unit (normalized to 1); i.e., $\kappa > 1$. Formally, the constraint of the remanufacturing capacity can be formulated as follows: $q_{rl} + \kappa q_{rh} \le \gamma q_1$. The IR's objective is to maximize profit by selecting the quantities of the high- and low-quality products, subject to the remanufacturing capacity constraint, as follows:

$$\max_{q_{rh} \ge 0, q_{rl} \ge 0} \quad \pi_r = (p_r - \delta c)(q_{rl} + q_{rh}) + \beta q_{rl} - F(q_{rl}) \tag{3}$$

$$\text{s.t.} \quad q_{rl} + \kappa q_{rh} \le \gamma q_1, \quad q_{rl} \ge 0, \quad q_{rh} \ge 0. \tag{4}$$

The parameter $0 < \delta < 1$ represents the unit aggregate cost of a remanufactured product incurred in production and in collection as a fraction of the new product cost. A higher value of δ causes the unit cost of a remanufactured product to be closer to that of a new product, indicating a smaller cost saving from remanufacturing.

When a larger amount of low-quality products is produced, the material cost savings will be higher but the expected incremental cost associated with, e.g., warranty costs, damage and faults, will also be higher. Hence, we denote β as the unit cost saving of a low-quality product and formulate the expected incremental cost as quadratic and convex in the amount of the low-quality products by considering $F(q_{rl}) \equiv (\tau \times q_{rl}^2)/2$.

Table 1: Summary of the scenarios and corresponding values of the Lagrangian multipliers

Remanufacturing capacity	IR's quality policies		
	$q_{rh} \geq 0, q_{rl} = 0$ (policy H)	$q_{rh} = 0, q_{rl} \geq 0$ (policy L)	$q_{rh} \geq 0, q_{rl} \geq 0$ (policy C)
Remanufacturing capacity is ample (status U)	$\lambda_k = 0, \lambda_h \geq 0, \lambda_l = 0$ (scenario HU)	$\lambda_k = 0, \lambda_h = 0, \lambda_l \geq 0$ (scenario LU)	$\lambda_k = 0, \lambda_h = 0, \lambda_l = 0$ (scenario CU)
Remanufacturing capacity is limited (status B)	$\lambda_k \geq 0, \lambda_h \geq 0, \lambda_l = 0$ (scenario HB)	$\lambda_k \geq 0, \lambda_h = 0, \lambda_l \geq 0$ (scenario LB)	$\lambda_k \geq 0, \lambda_h = 0, \lambda_l = 0$ (scenario CB)

We use the superscript "*" to denote the firms' subgame-perfect Nash equilibrium (SPNE) decisions. Using dynamic programming, the OEM's problem in the first period is given by

$$\max_{q_1 \geq 0} \ \Pi_o = \pi_1 + \pi_o^*, \tag{5}$$

where $\pi_o^* = \pi_o|_{q_o = q_o^*, q_{rh} = q_{rh}^*, q_{rl} = q_{rl}^*}$.

We first solve the problems of the OEM and IR in the second period. The Lagrangian function of the IR's problem in (3) and (4) is written as

$$L_r = \pi_r + \lambda_k(\gamma q_1 - q_{rl} - \kappa q_{rh}) + \lambda_h q_{rh} + \lambda_l q_{rl}, \tag{7}$$

where λ_k, λ_h, and λ_l are non-negative Lagrangian multipliers

According to the constraints of the IR's problem in (4), six possible scenarios combining three quality policies for the IR, i.e., H, C, and L, and two possible statuses for remanufacturing capacity, i.e., U and B, exist. The corresponding notation and the values of the Lagrangian multipliers in (7) are summarized in Table 1.

Similar to Atasu et al. (2008), Ferrer and Swaminathan (2006), and Wu (2012), we avoid trivial results by considering a sufficient condition, $\rho - (2c\delta)/(1 - \alpha + c) \geq 0$, such that $q_{rh} \geq 0$ and $q_{rl} \geq 0$. This condition indicates that when the consumer reservation price for remanufactured products is sufficiently high, entering the market is profitable for the IR, and thus the interaction between the OEM and IR emerges. In the following section, we discuss the firms' SPNE decisions based on the IR's production policies for clarity.

III. ANALYSIS

Based on prior studies (Atasu et al., 2008; Wu, 2015), we consider a representative parametric setting as a base example, as follows:
$c = 0.1$, $\beta = 0.03$, $\delta = 0.75$, $\rho = 0.6$, $\tau = 0.05$ and $\kappa = 1.2$.

We first examine the effects of the return rate γ on the equilibrium results and on IR scenario equilibrium choices.

We let $\alpha = 0.05$ for scenarios under policy H, $\alpha = 0.025$ for scenarios under policy C and $\alpha = 0.015$ for scenarios under policy L. The corresponding thresholds of γ under the quality policies can be obtained as follows: $\gamma^H = 0.8755$, $\gamma^C = 0.7179$, and $\gamma^L = 0.6920$. This result indicates that a larger amount of high-quality products chosen by the IR requires a greater return rate for ample capacity.

Figure 1 reveals that when the IR remanufacturing capacity is sufficient, the return rate is independent of the equilibrium decisions and thus has no effect on the firms' equilibrium profits, consumer surplus and social welfare. Moreover, the sufficiency of the IR remanufacturing capacity is profitable to the IR, consumers, and social welfare. Thus, the strategy where the IR reduces the quality level to pursue sufficient capacity is advantageous for both IR profits and consumer surplus, thus improving social welfare. However, when IR remanufacturing capacity is constrained, a greater return rate decreases the OEM but increases the IR equilibrium profits for all quality policies.

An increase in the return rate is also beneficial to consumers because decreasing prices increase consumer surplus. Nevertheless, the return rate is harmful to social welfare because of the significant decrease in OEM profits. Notably, an increase in the return rate even leads π_o^{HB*} to be smaller than π_o^{HU*}, meaning that when the return rate approaches the threshold, the OEM changes its preference to the scenario where the IR has ample capacity. In addition, the difference in IR profits under policies C and L is insignificant, whereas the differences in the OEM profit, consumer surplus, and social welfare are significant.

This result indicates that the motivation for the IR to choose the strategy with both the low- and high-quality products is not for individual profit but for the public benefit.

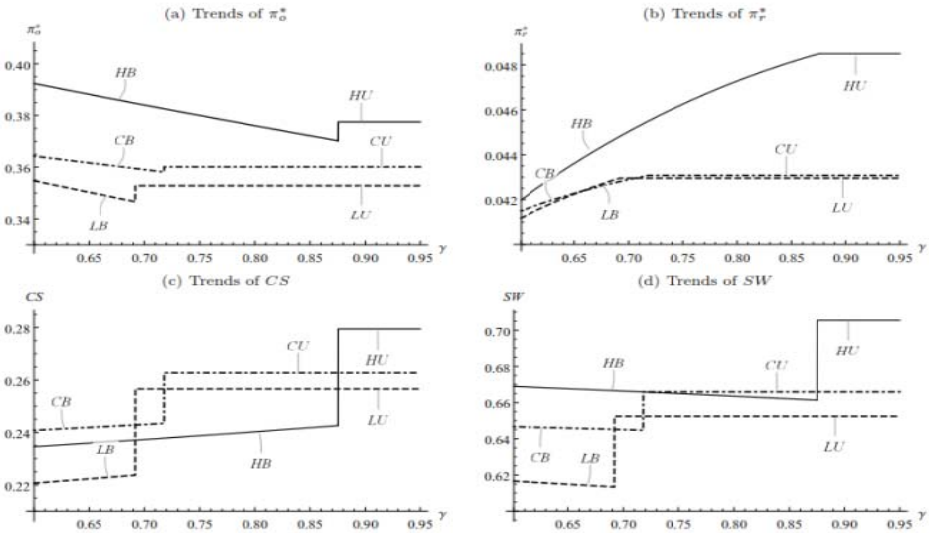


Figure 1: Effects of the return rate, γ, on the equilibrium results (policy H: $\alpha = 0.05$, policy C: $\alpha = 0.025$, and policy L: $\alpha = 0.015$)

We consider the effect of consumer quality sensitivity α and set $\gamma = 0.95$ for the status of unbinding remanufacturing capacity (status U) and $\gamma = 0.6$ for status B. Under these settings, the following conditions of α are obtained: $\alpha^{HU} = 0.03$, $\alpha^{LU} = 0.0169$, $\alpha^{HB} = 0.0426$, and $\alpha^{LB} = 0.0236$. When consumers are more sensitive to quality, new product sales are supported, and thus, the OEM's equilibrium profits increase under any quality policy chosen by the IR. Such an effect is more significant when the IR remanufacturing capacity is constrained. An increase in α also benefits consumers and social. However, an increase in α is not necessarily beneficial to the IR, specifically, when the IR chooses the low-quality policy. When the IR adopts policy L, an increase in α decreases the IR equilibrium profit because the sales margins must be decreased to stimulate consumer purchases. In contrast, when the IR chooses the high-quality policy, an increase in α decreases the intensity of competition such that it can preserve greater sales margins, leading to higher equilibrium profit. When the IR provides both low- and high-quality products, the equilibrium profits are slightly convex in α, but this variation is insignificant, indicating that the IR can adopt policy C to avoid the impact of consumer quality sensitivity. This insight suggests that when the IR capacity is not sufficiently high but the consumers are sensitive to quality, the IR should produce both low- and high-quality products to reduce the harm from consumers' high sensitivity to quality. This strategy is also favorable to social welfare compared to the pure low-quality strategy. As a result, when both scenarios CU and LB are available, the OEM and the IR prefer to adopt scenario CU, which is also more beneficial to consumer surplus and social welfare than scenario LB.

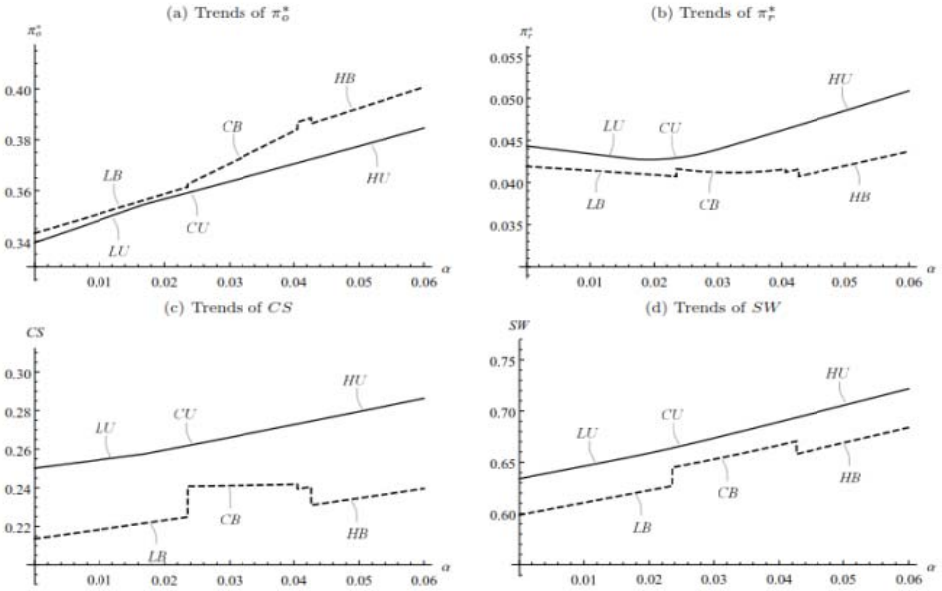


Figure 2: Effects of the consumers' quality sensitivity, α, on the equilibrium results (status U: $\gamma = 0.95$ and status B: $\gamma = 0.6$)

ACKNOWLEDGMENTS

This research was supported by the Ministry of Science and Technology, Taiwan, R.O.C.under MOST 106-2221-E-224-034-MY2.

REFERENCES

[1] Abbey, J. D., Meloy, M. G., Guide, V. D. R., Atalay, S., 2015. Remanufactured products in closed-loop supply chains for consumer goods. Production and Operations Management 24 (3), 488–503.

[2] Atasu, A., Sarvary, M., Van Wassenhove, L. N., 2008. Remanufacturing as a marketing strategy. Management Science 54 (10), 1731–1746.

[3] De Giovanni, P., Zaccour, G., 2014. A two-period game of a closed-loop supply chain. European Journal of Operational Research 232, 22–40.

[4] 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.

[5] D'Souza, C., Taghian, M., Khosla, R., 2007. Examination of environmental beliefs and its impact on the influence of price, quality and demographic characteristics with respect to green purchase intention. Journal of Targeting, Measurement and Analysis for Marketing 15 (2), 69–78.

[6] Ferguson, M., Guide, V. Daniel, J., Koca, E., Souza, G. C., 2009. The value of quality grading in remanufacturing. Production and Operations Management 18 (3), 300–314.

[7] Ferguson, M. E., Toktay, L. B., 2006. The effect of competition on recovery strategies. Production and Operations Management 15 (3), 351–368.

[8] Fleischmann, M., van Nunen, J., Graev, B., Gapp., R., 2004. Reverse logistics–capturing value in the extended supply chain.

[9] Galbreth, M. R., Blackburn, J. D., 2006. Optimal acquisition and sorting policies for remanufacturing. Production and Operations Management 15 (3), 384–392.

[10] Global Industry Analysts, Inc., 2015. Automotive parts remanufacturing–global strategic business report.

[11] Govindan, K., Soleimani, H., Kannan, D., 2015. Reverse logistics and closed-loop supply chain: A comprehensive review to explore the future. European Journal of Operational Research 240 (3), 603–626.

[12] Heese, H. S., Cattani, K., Ferrer, G., Gilland, W., Roth, A. V., Jul. 2005. Competitive advantage through take-back of used products. European Journal of Operational Research 164 (1), 143–157.

[13] Ilgin, M. A., Gupta, S. M., 2010. Environmentally conscious manufacturing and product recovery (ecmpro): A review of the state of the art. Journal of Environmental Management 91 (3), 563–591.

[14] Joshi, Y., Rahman, Z., 2015. Factors affecting green purchase behaviour and future research directions. International Strategic Management Review 3 (1-2), 128–143.

[15] Maiti, T., Giri, B. C., 2015. A closed loop supply chain under retail price and product quality dependent demand. Journal of Manufacturing Systems 37 (3), 624–637.

[16] Majumder, P., Groenevelt, H., 2001. Competition in remanufacturing. Production and Operations Management 10 (2), 125–141.

[17] Melumad, N. D., Ziv, A., 2004. Reduced quality and an unlevel playing field could make consumers happier. Management Science 50 (12), 1646–1659.

[18] Parker, D., Riley, K., Robinson, S., Symington, H., Tewson, J., Jansson, K., Ramkumar, S., Peck, D., 2015. Remanufacturing marketing study.

[19] Satyam, K., 2017. Automotive parts remanufacturing market: Global industry size, market trends, industry outlook and growth 2017-2025. http://techtopworld.com/2017/09/20/automotive-parts-remanufacturing-market-global-industry-size-market-trends-industry-outlook-growth-2017-2025/

[20] Souza, G. C., 2012. Closed-loop supply chains: A critical review, and future research. Decision Sciences 44 (1), 7–38.

[21] Steeneck, D. W., Sarin, S. C., 2013. Pricing and production planning for reverse supply chain: a review. International Journal of Production Research 51 (23-24), 6972–6989.

[22] Subramanian, R., Subramanyam, R., 2012. Key factors in the market for remanufactured products. Manufacturing & Service Operations Management 14 (2), 315–326.

[23] Teunter, R. H., Flapper, S. D. P., 2011. Optimal core acquisition and remanufacturing policies under uncertain core quality fractions. European Journal of Operational Research 210 (2), 241–248.

[24] Wei, S., Tang, O., Sundin, E., 2015. Core (product) acquisition management for remanufacturing: a review. Journal of Remanufacturing 5 (1).

[25] Wu, C.-H., 2015. Strategic and operational decisions under sales competition and collection competition for end-of-use products in remanufacturing. International Journal of Production Economics 169, 11–20.

★★★