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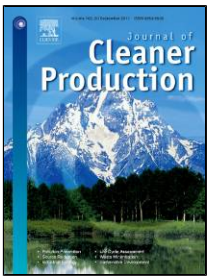

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Sustainable collaborative marketing governance mechanism for remanufactured products with extended producer responsibility

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ABSTRACT:

The marketing of remanufactured products has been receiving increasing attention from scholars and practitioners from the perspective of sustainable supply chain governance (SSCG) and extended producer responsibility (EPR). However, the research on remanufactured product marketing under EPR and SSCG mechanisms remains more new exploration. A mathematical model for remanufactured product marketing through the lenses of the Nash and Stackelberg game theory and the SSCG and EPR theories is proposed to deepen this issue in the literature based on the case of Caterpillar® (CAT), which is a benchmark producer that markets remanufactured products successfully. Findings include the characterization of three marketing decision models with EPR, namely, decentralized marketing decision under the weak dependence relation model, decentralized marketing decision under the strong dependence relation model, and collaborative marketing decision under the strong dependence relation model. Furthermore, this paper includes a classification of marketing governance mechanisms on the basis of the relation between CAT and its retailer and the identification of factors that sustain collaborative marketing governance mechanisms. The managerial insights obtained are useful to practitioners who are seeking for sustainable collaborative marketing governance mechanisms for remanufactured products under EPR and to scholars for further theory development.

***Keywords*:** Sustainability, extended producer responsibility, supply chain governance, remanufactured products, collaborative marketing

1. Introduction

Remanufacturing is a promising industry that may result in another industry civilization upgrade (Govindan, 2016). Remanufacturing is relevant to traditional manufacturing although essentially different from the traditional industry. Evolution, innovation, and consumption are

proven to be the core of the traditional industry philosophy based on the history of centuries of industrial civilization. The emergence of remanufacturing, which combines economy, environment, and society, boosts the revolution of traditional industrial civilization to some extent (Abbey, 2015b). The remanufacturing industry considers the survival of human beings, environment protection, and evolution with industrial development (Li, 2014). Thus, the remanufacturing industry is an international industry without a borderline (Guide, 2009; Xia, 2015). It represents the essential human industrial civilization, as well as reverse-fed to global because of excessive plunder of the traditional industry (Hatcher, 2011). In the world, all countries have been facing tremendous challenges and increasing bottlenecks with the increasing development opportunities. Government has made significant adjustments on regional economy and industrial development structures to promote and maintain sustainable growth, as well as to set several national policies to transform the society into an economical and green model. Enterprises gradually turned into global enterprises. Remanufacturing capability and the sustainability of remanufactured products can enhance their competitiveness in the global market. In addition, consumers are beginning to experience and accept remanufactured products with similar quality but lower price. Furthermore, consumer preferences have increased the consciousness of enterprises on environment protection responsibility.

Consequently, the government and enterprises have become aware of the importance of remanufactured product marketing for the sustainable growth of the remanufacturing industry. However, the development status of the remanufacturing industry does not satisfy the expectations of the government. A major problem is that remanufactured goods have not been selling well in the market. Furthermore, the scope of remanufactured goods marketing is limited. The research on national policies and enterprise practices remains more new exploration. Remanufactured products currently have two main marketing modes. One is the B2C mode in which consumers directly obtains remanufactured products, including mobile phones and other electronic products, via third party platforms, such as JingDong and other retail platforms in China. The other is the B2B mode, which is adopted by the marketing for CAT remanufactured products (Caterpillar®, a famous manufacturer and the largest remanufacturing company in the world). CAT, along with its retailers, sells its remanufactured products all over the world. CAT, along with its stakeholders, such as governments, retailers, and customers, creates a long-term sustainable governance model of the remanufacturing industry in China based on the contradictions and challenges, such as the lack of industrial access standards, the weakness of supervision power, and the mistiness of related regulation details, which the remanufacturing industry confronts at the initial stage. However, like other producers, CAT also faces challenges, such as governing the supply chain as the core enterprise, in its effort to achieve supply chain coordination with retailers under extended producer responsibility (EPR).

A theory was developed and a mathematical model with EPR was provided based on a commercial B2B CAT case by using the Nash and Stackelberg game theory from the sustainable supply chain governance (SSCG) perspective to deepen this issue. First, we study the operation mode of CAT and its relationship with retailers. Second, we build three game models, including the Nash, Stackelberg, and collaboration games, to study the connection between CAT and the retailers. Third, we introduce two kinds of marketing governance mechanisms and obtain several managerial insights. CAT and the retailers must negotiate the ratio of sales effort subsidy and the remaining profits within a reasonable range to achieve a win-win situation.

Our research contribution includes the following: 1) the characterization of three marketing decision models with EPR, namely, decentralized marketing decision under weak dependence relation, decentralized marketing decision under strong dependence relation, and collaborative marketing decision under strong dependence relation; 2) the classification of marketing governance mechanisms based on the relationships between CAT and the retailers through a comprehensive approach using a game theory and a case study; and 3) the identification of factors that influence sustainable collaborative marketing governance mechanisms, namely, social relation and sustainable product design. The use of three different theoretical lenses, including sustainability, EPR, and supply chain governance, allows for capturing and enriching the meaning of remanufactured product marketing and facilitates the identification and development of sustainability for the economy, environment, and society.

The paper is organized as follows. Section 2 reviews the literature on SSCG, EPR, and marketing of remanufactured products. Section 3 analyzes the sustainable operation mode of remanufactured CAT products. Section 4 builds three kinds of decision models in weak relation mode, strong relation mode, and cooperative mode. Section 5 discusses the marketing governance mechanism in different relation models via a comparative analysis. Section 6 concludes the paper with a summary of our main results, key managerial insights, research limitations, and suggestions for future research.

2. Literature reviews

2.1 Sustainable supply chain governance and remanufactured product

The supply chain governance (SCG) theory, as a new stream of research theory, states that cooperation, reputation risk, and reducing opportunism in the supply chain are the biggest challenge, the key concern, and the core effect of SCG, respectively (Li et al, 2014). In addition, the SCG theory is combined with sustainability. The coordinator reduces vulnerability by practicing sustainable SCG with the triple bottom line (TBL) rule (Vurro et al, 2009). From the sustainability perspective, the TBL theory includes three components, namely, economic, environmental, and social performances (Elkington, 2004). The balance among the three is also a concern. Hence, the three basic factors of

SSCG are institution, structures, and mechanisms. The mechanism that guides, regulates, and controls the activities come from the sustainable supply chain stakeholders (Li et al, 2014). SSCG is neither a decision-making process nor a management activity, but a framework in which decision-making is performed through the efficient and legitimate mechanism of sustainability governance in a supply chain (Li et al, 2014; Crisan and Parpucea, 2011). Generally, "*social relations*" and "*sustainable product design*" are the two focuses of scholars in the SSCG research field.

Social relation governance is an invisible supply chain governance mechanism (Li, 2016) in which effectiveness is reflected in the integration of tangible governance mechanisms, especially in the implementation of enterprise operation management. In this regard, Han et al. (2014) studied the influence of social relationship in the closed-loop supply chain and stressed that social relationship can affect the optimal decision of firms and reduce the double marginalization of the closed-loop supply chain. When the decision-making subject shows limited rationality and fairness, social relationship can also affect the degree of fairness. The relationship between two enterprises is a form of social relation, especially when both their identities have impacts on decision-making. Pang et al. (2014) analyzed the determinants of market price differences of new products in the E-retailing platform of eBay, in which the identity of the seller plays an important role in the price decision-making problem of remanufactured electronic products. In addition, the relation among enterprise, government, and public is an important factor in the enterprise decision-making behavior. Das and Dutta (2014) studied the design and cooperation of closed-loop supply chain under promotional price, considering the purchase intention of consumers based on the institutional environment of the entire society, such as the external pressure on the choice of the consumer.

Cradle to cradle is the design concept of sustainable products. The differences and robustness of product eco-designs, supply chain coordination with EPR, and production decisions (Kim, 2010) are the key issues in the sustainable product design phase. Such studies include the key stakeholders, namely, the establishment of incentives for legislators, sustainable product investors, sustainable product producers, and marketing of sustainable products. Plambeck and Wang (2009) explored the impact of electronic waste collection selection on the introduction of new products and stressed that the product's design can be achieved through the incentive of fee upon disposal regulation. Ba et al. (2013) studied the attitude of investors toward the environmental protection industry and concluded that the stock market has a positive reflection on the green development plan of the automobile industry. Agrawal and Ülkü (2013) studied the green design problem of products and stressed that module upgrade can accelerate product aging to improve product sustainability. Raz et al. (2013) studied the problems of product and process design for the environment and stressed that enterprises should increase their investment in functional and innovative products to improve their

environmental benefits. Wu (2013) explored the new product design problem of remanufactured products with competition from the perspective of the original equipment manufacturer (OEM) and found that an OEM product design strategy under competition is valid but does not necessarily damage their interest. Hwang et al. (2013) studied the sustainable design performance evaluation in the automotive industry and determined the most effective way to improve the ecological performance of the industry's products. Wang et al. (2013) proposed the construction of an ecological evaluation and decision support model for sustainable product development and design and provided the fuzzy network analysis method as an effective tool for the ecological evaluation of sustainable product design. Li et al. (2014) explored the application of governance mechanisms via a case study based on the seven sustainability commitments of H&M. Their findings suggest that the core influence and centrality of a corporation should be strengthened based on the perspective of internal governance; moreover, stakeholders should collaborate to achieve sustainability governance based on the perspective of external governance. Consequently, the sustainable design investment of remanufactured products and the collaboration of stakeholders are important components of SSCG.

2.2 Extended producer responsibility and remanufactured product

In 1990, Prof. Lindhqvist presented a formal definition of EPR in a report to the Environment Ministry of Sweden. Then, the revised definition of EPR was presented as a policy principle by Prof. Lindhqvist. He pointed out that EPR promotes the total life cycle environmental improvements of product systems by extending the responsibilities of the manufacturer to the entire life cycle of the product, especially to the take-back, recycling, and final disposal phases. EPR is implemented through administrative, economic, and informative policy instruments (Lindhqvist, 2000). Additionally, the Organization for Economic Co-operation and Development (OECD) published several reports for EPR policy, such as the Extended Producer Responsibility: A Guidance Manual for Governments (2001), the Economic Aspects of Extended Producer Responsibility (2004), and the Analytical Framework for Evaluating Costs and Benefits of EPR Programmes (2004). Combined with the practical background of China, Li et al.(2016) proposed for the EPR, as a kind of public insititution, to extend the environmental responsibility of producers to the consumer stage. EPR simultaneously focuses on the product waste stage and considers the design, production, distribution, retail, and other stages. Finally, the environmental behavior of producers can be restrained and inspired in the entire product life cycle under EPR.

In general, products of high recycling value and low environmental impact can spontaneously be recycled through a market recovery system without government intervention. Thus, the application of EPR products usually include the following categories: large quantity, low value, and high environmental risk products; both of the above two factors, and the low value of the waste recycling.

Enterprises, which include producers, sellers, and third party recycling enterprises, do not have the motivation to recycle these three types of products because of their threat to life. However, the potentially serious harm of these productsto the environment necessitates recycling Consequently, the government is obligated to intervene through the mandatory EPR implementation.

Credit is an important factor to enterprise decision-making and information sharing that should be considered in the recovery of EPR waste products. As such, Atasu and Souza (2013) studied the effects of quality on the efficiency of product recovery choice from the product quality perspective. In the recycling process, product recovery system, recycling mode, recycling cost structure, and product recycling legislation on the quality of products play important roles on the choice of product recovery. In particular, relevant EPR laws and regulations and the recycling of waste products have important impacts on the quality of product recovery. For enterprises, a good reputation entails high capital investment in the early stage and huge returns. In this regard, De Giovanni (2014) explored the coordination of a closed-loop supply chain under the income-sharing contract and found that the investment on green advertising and commercial credit increases the number of product sales and the rate of return, which provide a theoretical basis for the commercial value of credit. Aiming at the problem of customer return management, Ruiz et al. (2014) studied the information sharing between collecting points and central processing facilities and proved that excellent reputation can promote the effective sharing of information. Zhao et al. (2015) adopted a governance perspective to investigate the problem of integration for supply chain decision-making factors and governance mechanisms in the context of EPR. Their results show that optimal decision depends largely on the technological gap and degree of reliance among enterprises. The collective producer responsibility (CPR) mode is applicable in cases of large technological gap and strong degree of reliance, whereas individual producer responsibility (IPR) mode is more likely to be adopted by comparable companies with weak degree of reliance. Thus, the enterprise not only recovers the high value-added product parts, but the overall waste products under EPR. EPR can optimize the supply chain management structure and achieve the sustainable supply chain managementf through the strict control of enterprise recycling and remanufacturing behavior.

2.3 Marketing for remanufactured product

The marketing of remanufactured product is the focus of the remanufacturing field (Atasu, 2008). Many topics related to the marketing of remanufactured products have been investigated from different perspectives.

Shulman et al. (2009) studied optimal purchase cost and the recovery clause in the product recovery period. Their study provides the optimal policy function of the seller, which shows that the seller can use its price and the purchase price of the consumer market segments by considering the

strategic behavior of consumers. Through the analysis of the key factors in the market for remanufactured products, Subramanian and Subramanyam (2012) stressed that the reputation of the seller influences the price differences between new and old products. Ferrer and Swaminathan (2010) focused on the management of new products, differentiated remanufactured products, and pointed out the optimal production and pricing strategies. Considering the effect of remanufacturing products on new product sales, Guide and Li (2010) demonstrated that the competitive risk of old and new consumer products is low if the selection between them is not repeated; otherwise, the competition risk is high. Ovchinnikov (2011) showed that the price of new products is affected by the price of remanufactured products with a U-type trend; therefore, the enterprise should set the price of remanufactured products lower than the recent price without considering the new product. Agrawal et al. (2015) pointed out that the OEM will reduce the quality perception of new products by manufacturing their products; however, OEM will improve the quality perception of new products because products are remanufactured by third party enterprises.

Overall, the sustainable business development model considers the protection of environment and social welfare in the sustainability of manufacturing and service industries (Gunasekaran and Spalanzani, 2012). However, the contribution of remanufacturing to the sustainability of an enterprise is still a research challenge. Under government regulation, the external system pressure should be handled by enterprises and stakeholders together to act on their social responsibility and ensure the efficient coordination of the supply chain under EPR (Atasu, 2009). Thus, the breakthrough and innovation point of this paper is its focus on the sustainable collaborative marketing governance mechanism for remanufactured products with EPR.

3. Problem description

3.1. Case study: Sustainable operation mode of Caterpillar®

Caterpillar® (CAT) is the largest remanufacturing company in the world. An average of two million CAT "cores" are returned yearly. CAT designs and produces the most powerful and durable innovative machines and engines in the world. The products of CAT are excellent for customers, enterprises, and the environment. Sustainability is the core of CAT's operation strategy in China. CAT is aware that sustainability is very important to economic growth and economic growth is essential to its business and market services. CAT always seizes opportunities to develop efficient solutions for customers and their own business in either upward or downward economic situations. CAT strengthens its ability by pursuing sustainable development and progress to satisfy the emerging sustainability requirements of customers. One of the measures that CAT takes to achieve sustainable progress is remanufacturing, which collects end-of-life components and turns them into

remanufactured products, thereby saving a fraction of the cost while reducing the negative impact of wastes on the environment. CAT has currently combined its business interests with the goals of Chinese Sustainable Development by providing energy-efficient and environment-friendly products.

The strength and longevity of CAT rely on its ability to sustain long lasting, mutually rewarding relationships with its customers, dealers, distributors, suppliers, investors, and other institutions. CAT engages in meaningful dialogues with these stakeholders and appropriate governmental and non-governmental organizations. CAT continuously focuses on strengthening these relationships through conscientious and trustworthy actions. Collaboration is not only important for the successful social relation governance of CAT, but also has a significant role in the marketing of remanufactured products. Specifically, the distributors and retailers of CAT around the world serve as critical links to their customers. CAT relies on them to build and maintain the long-standing customer relationships that have made Caterpillar successful. CAT values their positive reputation and deep commitment to the customers and communities they serve. CAT maintains their relationships through trust, communication, and shared rewards. CAT works continuously with stakeholders to provide products, services, and support solutions to satisfy customer needs worldwide (CAT, 2016).

CAT significantly contributions to the sustainability of economy, environment, and society; however, several of CAT's remanufacturing processes are still unsustainable. Figure 1 shows the remanufacturing process of CAT based on official business documents. The details are as follows:

1) CAT launches the recycling program of old products based on a sustainable concept;

2) Old products are returned to the recycling center of CAT by customers under the guidance of CAT;

3) The recycling center of CAT tests old products according to a reward standard. The reward standard includes full, partial, and no refunds of product deposits;

4) CAT selects valuable components of the old products through testing;

5) Remanufactured products are obtained based on the valuable components through the manufacturing process;

6) Remanufactured products enter the next cycle after selling;

7) CAT does not pay the consumer deposit because old products have no value;

8) Old products become wastes that are discarded through informal channels or the garbage disposal plant because consumers have no motivation (e.g., incentives) to return old products;

9) The contribution of discarded wastes without a formal recycling process to environment pollution is becoming serious. Thus, the product is unsustainable.

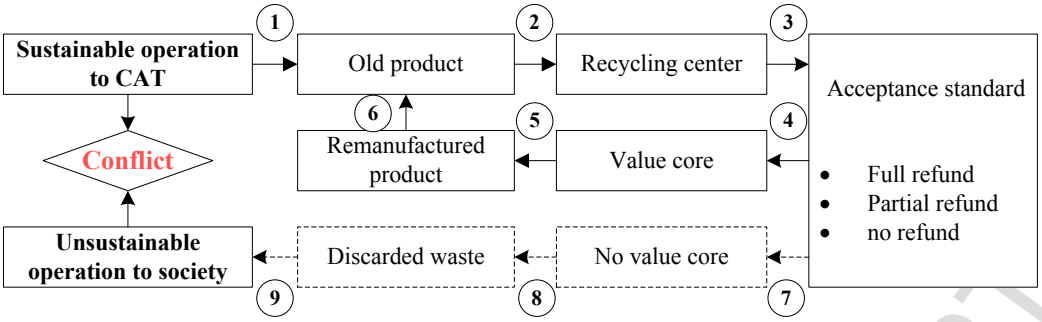

Fig. 1. Operation modes of the remanufactured products of CAT.

Figure 1 shows that the remanufacturing business model of CAT is unsustainable because old products are discarded and become wastes that pollute the environment, which is contradicting with its sustainable goals. The operation model of CAT will be genuinely sustainable with EPR. On the basis of the theoretical review of EPR, the principle stresses the responsibility for the full recovery of old products regardless of their value to reduce environment pollution due to wastes.

The expansion of the recovery scope of old products brings tremendous pressure to CAT. CAT needs to invest on remanufacturing technology to satisfy the recovery needs of old products and to improve the existing unsustainable operational model. Thus, the first challenge to CAT is capital investment. Remanufacturing capital investment not only increases the value of old products, but also helps improve the sustainability of remanufactured products. Remanufactured products are old products that are recycled and remanufactured through a reasonable and sustainable process. Thus, remanufactured products are sustainable. Consequently, the capital investment on remanufacturing is sustainable.

Additionally, its low price is one of the competitive advantages of remanufactured products, which is reduced with the increase in remanufacturing cost that can be decreased by capital investment. Therefore, such sustainable remanufactured products are accompanied by high marketing risk. Thus, the second challenge to CAT is reducing the risk perception of retailers to such sustainable remanufactured products through effective incentive policies and encouraging them to increase marketing efforts. Through collaborative marketing, CAT and its retailers can improve the market demand for sustainable remanufactured products together and achieve sustainable development for the remanufacturing industry.

This paper discusses the sustainable collaborative marketing governance mechanism of remanufactured products with EPR via game models to deal with the challenges in the case of CAT and its retailers.

3.2. Assumptions

1) The retailers of CAT are independent of one another. CAT cooperates with different retailers

in the actual collaborative marketing remanufacturing process. Supposing that retailers do not compete, this paper analyzes the cooperation mechanism between CAT and its retailers through the study of the sustainable collaborative marketing model between CAT and one of its retailers.

2) The total capital of sustainable collaborative marketing consists of the remanufacturing capital of CAT and the sales effort capital of the retailer. CAT is responsible for remanufacturing. Its specific capital investment includes: designing the products, procuring remanufacturing equipment, improving the remanufacturing technology, recycling old products, assembling the core parts of old products, remanufacturing products, performing market tests, selecting retailers, and procuring collaborative marketing contracts. The retailer is responsible for the sales management of remanufactured products. The retailer's specific capital investment includes the package design of remanufactured products, promoting the brand of remanufactured products, training sales staff, and designing the sales plan. Figure 2 shows the capital structure of sustainable collaborative marketing.

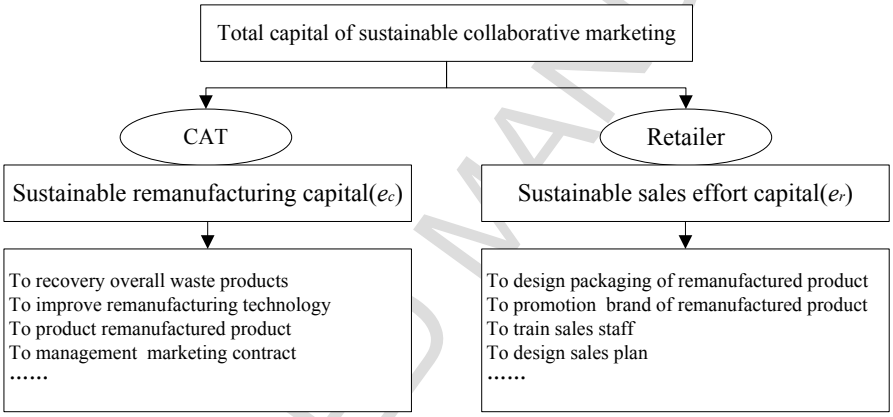

Fig. 2. Total capital structure of sustainable collaborative marketing

3) The sales quantity for remanufactured products is affected by the total capital of sustainable collaborative marketing. When the collaborative marketing scenario is not sustainable, the initial sales quantity of remanufactured products is:

$$q_0 = 1 - p\,. \qquad (1)$$

The sales quantity of remanufactured products increase with the sustainable investment level of the remanufacturing capital of CAT and the sale effort capital of retailers. In other words, the increment of the sales quantity is mainly determined by the sustainable investment level of the remanufacturing capital of CAT and the sale effort capital of retailers. Considering the non-linear sales quantity function, this paper assumes that the sales quantity function of remanufactured products per the Cobb–Douglas production function under the collaborative marketing mode is

$$q = 1 + ke_c^m e_r^n - p\,, \qquad (2)$$

where k is the coefficient of science and technology. The intensity of EPR policies in one country (e.g., China) affects the development level of science and technology. Therefore, k is an exogenous variable in this paper and $k > 0$; e_c is the sustainable investment level of the remanufacturing capital of CAT; m is the influence factor of sustainable investment level of the remanufacturing capital of CAT on q and $m > 0$; e_r is the sustainable investment level of the sale effort capital of the retailer; and n is the influence factors of sustainable investment level of the sale effort capital of the retailer on q and $n > 0$. The remanufacturing industry belongs to the knowledge dependence industry, and its marginal benefit decreases with the increasing level of knowledge and technology. Thus, $0 < m + n < 1$. p and $p > 0$ are the prices of remanufactured products.

4) CAT reduces the risk perception of the retailer by providing sales effort subsidy. The production and marketing of remanufactured products face great economic, ecological environment, social, and institutional risks because of the uncertainty of the remanufacturing technology development and sales quantity. CAT offers a certain ratio of sales effort subsidy represented by s_c, which is greater than of equal to zero and less than or equal to one to reduce the risk perception of retailers. Therefore, the manufacturer and its retailers share the risks to realize sustainable marketing for remanufactured products via the sales effort subsidy policy.

5) The total revenue generated by collaborative marketing is computed by multiplying the sustainable marginal revenue of remanufactured products by the sales quantity for remanufactured products with sustainable capital investment of CAT and its retailers. The profit of CAT is computed by subtracting the remanufacturing capital and sales effort subsidy from the total revenue; the profit of retailers is computed by subtracting the sales effort capital from the total revenue and sales effort subsidy. This paper assumes that whenever a sustainable remanufactured product is sold, the sustainable marginal revenue of CAT is a_c and the sustainable marginal revenue of retailer is a_r.

The symbols used in the subsequent discussion are listed in Table 1.

Table 1. Notations

Symbol	Description
e_c	Sustainable investment level of the remanufacturing capital of CAT
$e_{c\|c}$	Sustainable investment level of the remanufacturing capital of CAT because CAT is the leader
$e_{c\|c+r}$	Sustainable investment level of the remanufacturing capital of CAT under collaborative decision
s_c	Ratio of sales effort subsidy of CAT for retailer
$s_{c\|c}$	Ratio of sales effort subsidy of CAT for retailer as CAT is the leader
$s_{c\|c+r}$	Ratio of sales effort subsidy of CAT for retailer under collaborative decision
e_r	Sustainable investment level of the sales effort capital of the retailer
$e_{r\|c}$	Sustainable investment level of the sale effort capital of the retailer because CAT is the leader
$e_{r\|c+r}$	Sustainable investment level of the sale effort capital of the retailer under collaborative decision
q_0	Initial sales quantity for remanufactured products
q	Sales quantity for remanufactured products with sustainable capital investment of CAT and retailer
p	Price of remanufactured products
k	Coefficient of knowledge
m	Influence factors of sustainable investment level of the remanufacturing capital of CAT on q
n	Influence factors of sustainable investment level of the sale effort capital of the retailer on q
a_c	Sustainable marginal revenue of CAT for selling one remanufactured product
a_r	Sustainable marginal revenue of retailer for selling one remanufactured product
Π_c	Sustainable profit of CAT
$\Pi_{c\|c}$	Sustainable profit of CAT because CAT is the leader
$\Pi_{c\|c+r}$	Sustainable profit of CAT under collaborative decision
Π_r	Sustainable profit of retailer
$\Pi_{r\|c}$	Sustainable profit of retailer as CAT is the leader
$\Pi_{r\|c+r}$	Sustainable profit of retailer under collaborative decision
Π_{c+r}	Sustainable profit of the entire supply chain

4. Model Constructions

4.1 Decentralized marketing decision under weak dependence

In the weak dependence relation model with EPR, the power gap among governance subjects is small and governance subjects tend to make decisions individually (Zhao, 2015). That is, CAT and the retailer make decentralized decisions on investment level because they are independent of each other. They select the strategy with the smallest loss to maximize their respective profits. Figure 3 shows the process of decentralized marketing decision the under weak dependence model.

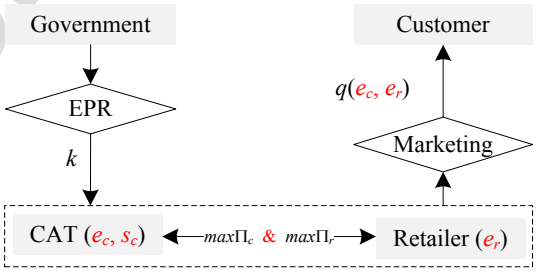

Fig. 3. Decentralized marketing decision under weak dependence.

1) Decision of CAT and retailer

CAT makes decisions on $e_c \geq 0$ and $0 \leq s_c \leq 1$ to maximize its own profit:

$$\Pi_c = a_c(q - q_0) - e_c - s_c e_r . \quad (3)$$

Meanwhile, the retailer decides on $e_r \geq 0$ to maximize its own profit:

$$\Pi_r = a_r(q - q_0) - e_r + s_c e_r . \quad (4)$$

The main result of Proposition 1 is summarized by Eqs. (1) and (2).

Proposition 1. In the weak dependence relation model with EPR, the optimal ratio of the sales effort subsidy of CAT for the retailer is zero, and the optimal sustainable investment level of the remanufacturing capital of CAT is

$$e_c^* = (kma_c e_r^n)^{\frac{1}{1-m}}; \quad (5)$$

and the optimal sustainable investment level of the sales effort capital of the retailer is

$$e_r^* = (kna_r e_c^m)^{\frac{1}{1-n}}. \quad (6)$$

Proof of Proposition 1. e_c^* and e_r^* satisfy the first order optimal condition, which makes the first derivative of Π_c and Π_r zero based on the concavity of Π_c and Π_r. The subsidy policy does not influence the sales quantity of remanufactured products. Thus, CAT can maximize its profit when the distribution of sales effort subsidy is zero. Hence, Proposition 1.

2) Optimal decisions of CAT and its retailer

Proposition 2 can be obtained through Eqs. (5) and (6).

Proposition 2. In the weak dependence relation model with EPR, the sustainable investment level of CAT is optimal at a certain remanufacturing capital, ratio of sales effort subsidy of CAT for its retailer, and sustainable investment level of the sales effort capital of the retailer that maximizes their respective profits. The optimal values are derived through Eqs. (7), (8), and (9):

$$e_c^* = [k(ma_c)^{1-n}(na_r)^n]^{1/1-m-n}, \quad (7)$$

$$s_c^* = 0, \quad (8)$$

$$e_r^* = [k(na_r)^{1-m}(ma_c)^m]^{1/1-m-n}. \quad (9)$$

Proposition 2 shows that in the weak dependence relation model with EPR, the marginal revenue of remanufactured products is positively correlated with the level of CAT's sustainable investment and the retailer's level of sales effort because the subsidy policy of CAT will not directly affect the market demand of remanufactured products. Thus, the retailer's level of sales effort is not affected by the subsidy policy and CAT will not provide sales subsidy for its retailers.

4.2 Decentralized marketing decision under strong dependence

In the strong dependence relation model with EPR, the power gap among governance subjects is wide and governance subjects tend to make decisions collectively (Zhao, 2015). The interaction between CAT and its retailers under collective decision-making is strong. The retailer makes optimal decisions based on the decisions of CAT because CAT is the leader. In other words, CAT makes

decisions on remanufacturing investment and sales subsidy first. Then, the retailer makes decisions on sales effort to maximize its own profit. Figure 4 shows the process of decentralized marketing decision the under weak dependence model.

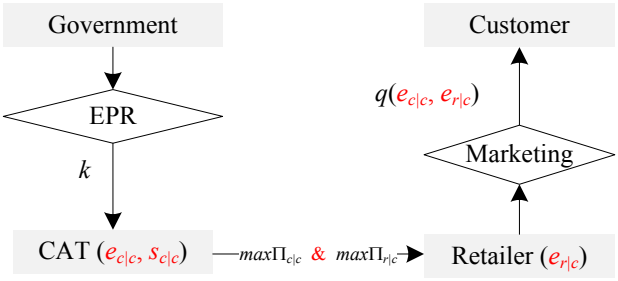

Fig. 4. Decentralized marketing decision under strong dependence.

1) Decisions of the retailer

On the basis of backward induction (Fudenberg, 2002), the retailer first decides on the investment level of the sales effort capital $e_{r|c}$ given $e_{c|c}$ and $s_{c|c}$ to maximize its own profit:

$$\Pi_{r|c} = a_r(q - q_0) - e_{r|c} + s_{c|c}e_{r|c}. \qquad (10)$$

Proposition 3 can be deduced from Eq. (10).

Proposition 3. In the strong dependence relation model with EPR, given the sustainable investment level of CAT's remanufacturing capital and the ratio of sales effort subsidy of CAT for the retailer with EPR, the optimal sustainable investment level of the retailer's sales effort capital is

$$e^*_{r|c} = \left(\frac{kna_r e^m_{c|c}}{1 - s_{c|c}}\right)^{\frac{1}{1-n}}. \qquad (11)$$

Proof of Proposition 3. $e^*_{r|c}$ satisfies the first-order optimal condition, which makes the derivative of $\Pi_{r|c}$ zero based on the concavity of $\Pi_{r|c}$. Hence, Proposition 3.

Proposition 3 shows that in the strong dependence relation model with EPR, the more sales subsidy CAT gives, the higher the sustainable investment level of the retailer's sales effort capital. Moreover, the higher the sustainable investment level of CAT's remanufacturing capital, the higher the sustainable investment level of the retailer's sales effort capital. Thus, CAT motivates its retailers to increase the investment level of sales efforts by increasing the level of its own remanufacturing capital investment and the ratio of sales effort subsidy. Finally, the total sales of remanufactured products increases because of the joint efforts of CAT and its retailers.

2) Optimal decisions of CAT and its retailers

As the leader, CAT makes decision on $e_{c|c}$ and $s_{c|c}$ to motivate its retailers to adopt optimal sustainable sales effort to maximize its profit:

$$\Pi_{c|c} = a_c(q - q_0) - e_{c|c} - s_{c|c}e^*_{r|c}. \qquad (12)$$

Proposition 4 is derived based on Eqs. (11) and (12).

Proposition 4. In the strong dependence relation model with EPR, the optimal sustainable investment level of the remanufacturing capital $e_{c|c}^*$ of CAT, ratio of sales effort subsidy of CAT for retailer $s_{c|c}^*$, and sustainable investment level of retailer's sales effort capital $e_{r|c}^*$ is one, to maximize their respective profits. The optimal values of $\left\{e_{c|c}^*, s_{c|c}^*, e_{r|c}^*\right\}$ are derived by Eqs. (13), (14) and (15), respectively.

$$e_{c|c}^* = [km^{1-n}n^n(a_c + na_r)]^{1/(1-m-n)}, \quad (13)$$

$$s_{c|c}^* = [a_c - (1-n)a_r]/(a_c + na_r), \quad (14)$$

$$e_{r|c}^* = [km^m n^{1-m}(a_c + na_r)]^{1/(1-m-n)}. \quad (15)$$

Proof of Proposition 4. $e_{c|c}^*$ and $s_{c|c}^*$ satisfies the first and second order optimal conditions based on the concavity of $\Pi_{c|c}$. Thus, Proposition 4 can be easily obtained.

Proposition 4 shows that the optimal decisions in the strong dependence relation model with EPR. As a leader, the ratio of CAT's sales effort subsidy is positively correlated with the marginal revenue of CAT, but is negatively correlated with the marginal revenue of the retailer. When $a_c/a_r \geq 1-n$, the ratio of CAT's sales effort subsidy is positively correlated with a_c/a_r. When the marginal revenue of CAT is high, CAT will increase the ratio of sales effort subsidy to encourage the retailer to increase its sales efforts to increase the sales quantity of remanufactured products. Even if CAT reduces the sales effort subsidy to increase the sales quantity of the remanufactured products, the retailer will still increase the investment level on sales effort when its marginal revenue is high.

4.3 Collaborative marketing decision under strong dependence

The relationship between CAT and the retailer under collective decision-making is not a sequential game. In the case of collaborative cooperation, CAT and the retailer make collaborative centralized decisions based on the profit optimization principle of the entire supply chain. That is, to maximize the total profit of the entire supply chain, CAT decides on the investment level of remanufacturing capital and the ratio of sales effort subsidy, while the retailer decides on the investment level of sales efforts. Figure 5 shows the process of collaborative marketing decision under the strong dependence.

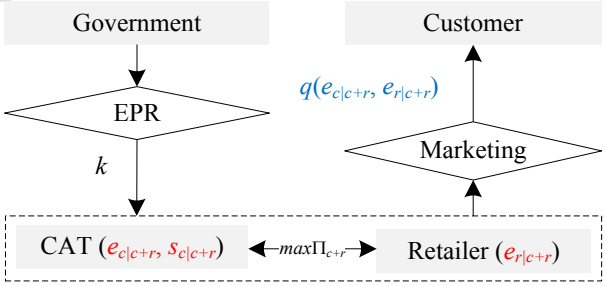

Fig. 5. Collaborative marketing decision under strong dependence.

1) Optimal decisions of CAT and the retailer

CAT decides on the investment level of remanufacturing capital $e_{c|c+r}$ and the ratio of sales effort subsidy $s_{c|c+r}$, while the retailer decides on the investment level of sales effort capital $e_{r|c+r}$ to maximize the total profit of the entire supply chain:

$$\Pi_{c+r} = (a_c + a_r)(q - q_0) - e_{c+r} - e_{c+r}. \qquad (16)$$

Proposition 5 is obtained by making the partial derivative zero to take the first order partial derivative of $e_{c|c+r}$ and $e_{r|c+r}$.

Proposition 5. The optimal sustainable investment level of CAT's remanufacturing capital $e^*_{c|c+r}$ and the sustainable investment level of the retailer's sales effort capital $e^*_{r|c+r}$ in the strong dependence relation model with EPR is one to maximize the total profit of the entire supply chain in the decision process of collaborative marketing. The optimal solutions $\{e^*_{c|c+r}, e^*_{r|c+r}\}$ are as follows:

$$e^*_{c|c+r} = [km^{1-n}n^n(a_c + a_r)]^{1/(1-m-n)}, \qquad (17)$$

$$e^*_{r|c+r} = [km^m n^{1-m}(a_c + a_r)]^{1/(1-m-n)}. \qquad (18)$$

Proof of Proposition 5. $e^*_{c|c+r}$ and $e^*_{r|c+r}$ satisfy the first order and second order optimal conditions based on the concavity of Π_{m+r}. Thus, Proposition 5 can easily be obtained.

5. Results discussion

Table 2 shows that two marketing governance mechanisms, namely, decentralized marketing governance mechanism and collaborative marketing governance mechanism, between CAT and its retailers in the remanufactured product marketing mode with EPR are observed based on the analysis above.

Table 2

Sustainable marketing governance mechanism of CAT and retailer with EPR.

Governance mechanism	CAT	Retailer	Relation model
Decentralized marketing governance	$\Pi^*_c(e^*_c, s^*_c, e^*_r)$	$\Pi^*_r(e^*_c, s^*_c, e^*_r)$	weak dependence
	$\Pi^*_{c\|c}(e^*_{c\|c}, s^*_{c\|c}, e^*_{r\|c})$	$\Pi^*_{r\|c}(e^*_{c\|c}, s^*_{c\|c}, e^*_{r\|c})$	strong dependence
Collaborative marketing governance	$\Pi^*_{c\|c+r}(e^*_{c+r}, s^*_{c+r}, e^*_{c+r})$	$\Pi^*_{r\|c+r}(e^*_{c+r}, s^*_{c+r}, e^*_{c+r})$	

5.1 Decentralized marketing governance mechanism

First, this paper defines the optimal difference between CAT's profits in the cases of strong- and weak- dependence relations as $\Delta\Pi_c = \Pi^*_{c|c} - \Pi^*_c$. Basar and Olsder (1998) proposed a proposition that provides a sufficient condition under which the leader never does worse in a "Stackelberg game" than in a "Nash game." In addition, they pointed out from the perspective of followers that the equilibrium strategy in a Stackelberg game is an optimal response to the announced Stackelberg

strategy of the leader. That is, $\Delta\Pi_c > 0$. Therefore, as the leader of the supply chain, CAT should build a strong dependence relationship with the retailer to control the decision of the retailer rather than the weak dependence of decentralized marketing governance mechanism.

Second, this paper defines the difference between the optimal sustainable investment levels of CAT in the two relation models as $\Delta e_c = e^*_{c|c} - e^*_c$. By combining Eqs. (7) and (13), the following formula with $0 < m + n < 1$ can be presented by assuming that $\Delta e_c = (km^{1-n}n^n)^{1/1-m-n} a_c^{1/1-m-n}[(1+n\,a_r/a_c)^{1/1-m-n} - (a_r/a_c)^{n/1-m-n}]$. Thus, if $(a_r/a_c)^n - n\,a_r/a_c < 1$, then $\Delta e_c > 0$; otherwise, if $(a_r/a_c)^n - n\,a_r/a_c \geq 1$, then $\Delta e_c \leq 0$. Thus, when $(a_r/a_c)^n - n\,a_r/a_c < 1$, the sustainable investment level of CAT in the strong dependence relation mode is higher than the level of investment in the weak dependence relation.

Third, this paper defines the difference between the retailer's optimal profit in the strong- and weak- dependence relations as $\Delta\Pi_r = \Pi^*_{r|c} - \Pi^*_r$. By combining Eqs. (7)–(9) and (13)–(15), this paper obtains $\Delta\Pi_r = (1-n)(km^m n^n)^{1/1-m-n} a_r a_c^{m+n/1-m-n}[(1+n\,a_r/a_c)^{m+n/1-m-n} - (a_r/a_c)^{n/1-m-n}]$.
Thus, if $(a_r/a_c)^{n/m+n} - n\,a_r/a_c < 1$, then $\Delta\Pi_r > 0$; otherwise, if $(a_r/a_c)^{n/m+n} - n\,a_r/a_c \geq 1$, then $\Delta\Pi_r \leq 0$. Thus, when $(a_r/a_c)^{n/m+n} - n\,a_r/a_c < 1$, the retailer would like to build a strong dependence relation model with CAT, considering the first decision of CAT. On the contrary, the weak dependence relation model is the best choice for the retailer.

Fourth, this paper defines the difference between the retailer's optimal sustainable sale effort level in the two relation models as $\Delta e_r = e^*_{r|c} - e^*_r$. By combining Eqs. (9) and (15), this paper obtains $\Delta e_r = (km^m n^{1-m})^{1/1-m-n} a_c^{1/1-m-n}[(1+n\,a_r/a_c)^{1/1-m-n} - (a_r/a_c)^{1-m/1-m-n}]$. Moreover, if $(a_r/a_c)^{1-m} - n\,a_r/a_c < 1$, then $\Delta e_r > 0$; otherwise, if $(a_r/a_c)^{1-m} - n\,a_r/a_c \geq 1$, then $\Delta e_r \leq 0$. Thus, when $(a_r/a_c)^{1-m} - n\,a_r/a_c < 1$, the sustainable sale effort level of the retailer in the strong dependence relation mode is higher than that in the weak dependence relation.

Additionally, Eqs. (9) and (15) show that CAT does not need to subsidize the sales efforts of retailers in the weak dependence relation model. However, CAT should encourage retailers to improve sales efforts through the subsidy policy in the strong dependence relation model. CAT should consider the marginal revenue ratio of remanufactured products and the impact of the sales effort of the retailer on the market demand for remanufactured products to optimize the proportion of sales subsidy.

Table 3 shows the results of the discussions.

5.2 Collaborative marketing governance mechanism

A win-win situation is the most fundamental premise in collaborative marketing. In other words, CAT and the retailers can achieve profit maximization for the entire supply chain by maximizing the profits of both. $(a_r/a_c)^{n/m+n} - n\,a_r/a_c < 1$ because the strong dependence relation mode is more likely

to promote collaborative decision-making. The,n $\Delta\Delta\Pi_c = \Pi^*_{c|c+r} - \Pi^*_{c|c}$ and $\Delta\Delta\Pi_r = \Pi^*_{r|c+r} - \Pi^*_{r|c}$ are suitable for analyzing the collaborative marketing governance mechanism.

This paper obtains the following formulas $\Delta\Delta\Pi_c = ka_c[(e^*_{c|c+r})^m(e^*_{r|c+r})^n - (e^*_{c|c})^m(e^*_{r|c})^n] - (e^*_{c|c+r} - e^*_{c|c}) - (s_{c|c+r}e^*_{r|c+r} - s^*_{c|c}e^*_{r|c})$ based on Formulas (13)–(15) and (17)–(18). This paper defines $G = ka_c[(e^*_{c|c+r})^m(e^*_{r|c+r})^n - (e^*_{c|c})^m(e^*_{r|c})^n] - (e^*_{c|c+r} - e^*_{c|c}) + s^*_{c|c}e^*_{r|c}$, thus $\Delta\Delta\Pi_c = G - s_{c|c+r}e^*_{r|c+r}$ for the convenience of analysis. Similarly, this paper obtains $\Delta\Delta\Pi_r = ka_r[(e^*_{c|c+r})^m(e^*_{r|c+r})^n - (e^*_{c|c})^m(e^*_{r|c})^n] - (e^*_{r|c+r} - e^*_{r|c}) + (s_{c|c+r}e^*_{r|c+r} - s^*_{c|c}e^*_{r|c})$. Then, to define $H = ka_r[(e^*_{c|c+r})^m(e^*_{r|c+r})^n - (e^*_{c|c})^m(e^*_{r|c})^n] - (e^*_{r|c+r} - e^*_{r|c}) - s^*_{c|c}e^*_{r|c}$, we obtain $\Delta\Delta\Pi_c = H + s_{c|c+r}e^*_{r|c+r}$. Moreover, if $s_{c|c+r} < G/e^*_{r|c+r}$, then $\Delta\Delta\Pi_c > 0$; and if $s_{c|c+r} > -H/e^*_{r|c+r}$, then $\Delta\Delta\Pi_r > 0$. If $H < 0$, then $0 \le -H/e^*_{r|c+r} < s_{c|c+r} < G/e^*_{r|c+r} \le 1$ because $0 \le s_{c|c+r} \le 1$.

Therefore, when $0 \le -H/e^*_{r|c+r} < s_{c|c+r} < G/e^*_{r|c+r} \le 1$, $\Delta\Delta\Pi_c > 0$ and $\Delta\Delta\Pi_r > 0$ can be achieved. Thus, the collaborative marketing of remanufactured products between CAT and the retailer is feasible. Therefore, CAT and the retailers must negotiate the ratio of sales subsidy $s_{c|c+r}$ and the remaining profit $\Delta\Delta\Pi_c + \Delta\Delta\Pi_r$ to achieve a win-win situation.

Table 3 shows the results of the discussions.

Table 3

Sustainable marketing governance model selections of CAT and retailer with EPR in different constraints.

Subjects	Constraints	Results	Governance model selections
CAT	unconstrained	$\Pi^*_{c|c} > \Pi^*_c$	Decentralized strong dependence relation
	$(a_r/a_c)^n - n a_r/a_c < 1$	$e^*_{c|c} > e^*_c$	N/A
	$(a_r/a_c)^{n/m+n} - n a_r/a_c \ge 1$	$e^*_{c|c} \le e^*_c$	N/A
Retailer	$(a_r/a_c)^{n/m+n} - n a_r/a_c < 1$	$\Pi^*_{r|c} > \Pi^*_r$	Decentralized strong dependence relation
	$(a_r/a_c)^{n/m+n} - n a_r/a_c \ge 1$	$\Pi^*_{r|c} \le \Pi^*_r$	Decentralized weak dependence relation
	$(a_r/a_c)^{1-m} - n a_r/a_c < 1$	$e^*_{r|c} > e^*_r$	N/A
	$(a_r/a_c)^{1-m} - n a_r/a_c \ge 1$	$e^*_{r|c} \le e^*_r$	N/A
CAT & Retailer	$(a_r/a_c)^{n/m+n} - n a_r/a_c < 1$ & $0 \le -H/e^*_{r|c+r} < s_{c|c+r} < G/e^*_{r|c+r} \le 1$	$\Pi^*_{c|c+r} > \Pi^*_{c|c}$ & $\Pi^*_{r|c+r} > \Pi^*_{r|c}$	Collaborative strong dependence relation

6. Conclusions and implications

6.1. Academic contributions

Although the literatures on marketing for remanufactured products are flourishing, limited attention has been paid to governance mechanisms that are activated by enterprises with sustainable supply chain under the extended producer responsibility. This research provides a mathematical basis through a case analysis and uses the Nash and Stackelberg game, SSCG, and EPR theories to study the research problem. Specific gaps in the literature are addressed as follows:

1) Prior studies have explored different approaches to the marketing for remanufactured products. However, limited extant research has focused on the sustainability issues of remanufactured marketing in closed-loop supply chains (Abbey, 2015a) or sustainable supply chain with EPR (Zhao, 2015). Building on the existing findings regarding different SSCG models (Li, 2015) and EPR models (Atasu, 2012), this work enhances the characterization of three sustainable marketing decision models with EPR, namely, decentralized marketing decision under weak dependence relation, decentralized marketing decision under strong dependence relation, and collaborative marketing decision under strong dependence relation.

2) Existing SSCG literature shows the positive value of case and mathematical studies in exploring the validity and rationality of the SSCG mechanism. A comprehensive approach has been claimed in the literature to have built the theory that explains different marketing approaches (Formentini,2016; Govindan, 2015). Our study contributes to the fulfilment of this gap. Specifically, this paper provides a classification of marketing governance mechanisms on the basis of the relation model of CAT with its retailers, including the decentralized and collaborative marketing governance mechanisms, based on the comprehensive approach of the game and the case study.

3) Present research in the field of marketing for remanufactured products calls for the design of remanufactured products and multi-stakeholder collaboration (Airike, 2016) as part of the business strategy of an organization, which are considered as main factors in remanufacturing research. Therefore, the influence factors of marketing of remanufactured products are identified using two theoretical bases. On the basis of the SSCG theory, social relation and sustainable product design are considered. The responsibility of CAT in the entire life cycle and supply chain structure of products based on different relation models is explored based on the EPR theory. To sum up, this paper provides the identification of factors that constitute the sustainable collaborative marketing governance mechanisms.

6.2. Practical implications

The findings of this research can provide valuable insights for the industry and practitioners. Results suggest that to achieve a win-win situation, CAT and its retailers must negotiate the ratio of sales subsidy policies and the remaining profits in the collaborative marketing process for remanufactured products.

Therefore, in the weak dependence relation model with EPR, the marginal revenue of remanufactured products is positively correlated with the sustainable investment level of CAT's remanufacturing capital and the retailer's sales efforts capital because the sales effort subsidy policy of CAT will not directly affect the sale quantity of remanufactured products. In other words, the investment level of the retailer's sales effort is not affected by the subsidy policy; thus, CAT will not

provide retailers with sales effort subsidy.

Moreover, this research indicates that in the strong dependence relation model with EPR, the more sale subsidies CAT provides, the higher the sustainable investment level of the retailer's sales effort capital; the higher the sustainable investment level of CAT's remanufacturing capita, the higher the sustainable investment level of the retailer's sales effort capital. Thus, CAT motivates retailers to increase investment their level of sales efforts capital by increasing its own sustainable investment level of remanufacturing capital and the ratio of sales effort subsidy. Finally, the sales quantity of remanufactured products is increased with the joint efforts of CAT and the retailers.

Several interesting implications in strong dependence relation model with EPR are discovered. As the leader in the supply chain, the ratio of sale effort subsidy of CAT is positively correlated with the marginal revenue of CAT, but is negatively correlated with marginal revenue of the retailers. When the ratio of the marginal revenue of CAT and the marginal revenue of retailer is greater than or equal to the constant value, the ratio of sale effort subsidy of CAT is positively correlated with the marginal returns ratio of CAT and the retailers. When the marginal revenue of CAT is higher, CAT will increase the ratio of sale effort subsidy to encourage the retailers to increase sales efforts to increase market demand for remanufactured products. Even if CAT reduces the proportion of sales subsidies the retailers will still increase sales effort level when the retailer's marginal efficiency is higher to increase the market demand.

Eventually, we suggest that CAT should build a strong dependence relation model with the retailers rather than a weak dependence, which is a feature of the decentralized marketing governance mechanism. As the leader of the supply chain, CAT can control the decision of the retailer. CAT and the retailers must negotiate the ratio of sales effort subsidy and the remaining profits based on the sustainable collaborative marketing governance mechanism for remanufactured products under EPR to achieve a win-win situation.

6.3. Limitations and future research opportunities

The limitations and future research opportunities of this paper are summarized as follows;

First, only one case sample is analyzed in this paper. Thus, the regional characteristics of the country limit the universality of the research results. However, CAT cases in international supply chains have been selected to reduce this limitation and support the universality of results. Future studies are encouraged to explore the transnational supply chain structure as a sustainable governance factor in the marketing for remanufactured products. Moreover, this paper only uses a successful remanufacturing enterprise as sample, and no comparative analysis of success and failure is performed. Thus, a certain industry bias exists. Further research on multiple cases based on our results will be developed to obtain an extensive perspective.

Second, the government decision on EPR is exogenous in this paper. Future research should investigate the indigeneity of the government and NGOs to improve our model on marketing decisions with different dependence relations under the EPR. Meanwhile, this work deepens our comprehension of the implementation of the sustainable collaborative marketing governance mechanism in the supply chain under EPR.

Third, this paper does not focus on the reasonable ratio of remaining profits in the collaborative marketing governance mechanism. However, we provide a feasible selection interval for sale effort subsidy policy. This is a meaningful area for future research.

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