Received 25 February 2019
Revised 7 July 2019
Accepted 19 August 2019

Circular business models generation for automobile remanufacturing industry in China

Barriers and opportunities

Jing Shao
School of Management, Northwestern Polytechnical University, Xi'an, China
Shuo Huang
School of Automation, Northwestern Polytechnical University, Xi'an, China
Isaac Lemus-Aguilar
School of Management, Politecnico di Milano, Milan, Italy and Department of Industrial Engineering, Business Administration and Statistics, Universidad Politécnica de Madrid, Madrid, Spain, and
Enes Ünal
School of Management, Politecnico di Milano, Milan, Italy and Department of Industrial Economics and Management, KTH Royal Institute of Technology, Stockholm, Sweden

Abstract

Purpose – Although China can be considered an early adopter of the circular economy, there are few studies of remanufacturing business models (BMs) in the context of the Chinese automobile industry. The purpose of this paper is to investigate viable BMs, summarizes current obstacles and anticipates future development opportunities and directions.

Design/methodology/approach – The cross-case analysis considers the roles of value networks and of customer value proposition and interface in circular business models (CBMs) by examining the strategies and tactical measures of two leading remanufacturers. The data are collected from semi-structured interviews, documents, etc.

Findings – The analysis identifies the following components of viable BMs of remanufacturers: reclaiming raw material, managing used components, producing new products and marketing. Several current obstacles are summarized from four perspectives: policy barriers and insufficient government support; consumer awareness; related product quality; and technology. The study also identifies future directions and opportunities for the automobile parts remanufacturing industry.

Originality/value – This study contributes to the CBM literature by mapping the barriers and opportunities in remanufacturing. The results have shed some light into the field of sustainability in manufacturing firms by empirically testing the theoretical model. The results will help managers to design viable CBMs in different contexts.

Keywords Manufacturing management, Design for manufacture, Sustainable production, Green operations, Automotive industry

Paper type Research paper

This research was supported by The National Natural Science Fund (No. 71704142), Philosophy and Social Science Foundation of Shaanxi Province (2017S036) and the Soft Science Foundation of Shaanxi Province (2018KRM048). It is also partly conducted within the framework of the European Doctorate in Industrial Management (EDIM), which is funded by the Education, Audio-visual and Culture Executive Agency (EACEA) of European Commission under Erasmus Mundus Action 1 programs.

Journal of Manufacturing Technology Management
Vol. 31 No. 3, 2020
pp. 542-571

1741-038X
DOI 10.1108/JMTM-02-2019-0076

1. Introduction

The growing demand for consumer products has led to severe environmental degradation and poses a mounting threat to sustainable development (Shao, 2019). In response to the challenges of sustainable development, over the last decade, academics and industry leaders have become interested in the concept of the circular economy (CE) as a replacement for the prevailing linear economic system of "take, make and dispose." Applying the 3Rs, "Reduce, Reuse and Recycle," to production, distribution and consumption processes would fundamentally change the business growth cycle. Currently, CE is a generic concept that encompasses a variety of sustainability approaches (Ghisellini *et al.*, 2016), such as regenerative design, remanufacturing, performance economy, biomimicry, cradle-to-cradle processes, industrial ecology and the blue economy. Both China and Europe are promoting the development of a CE, and it is becoming an integral part of policy making (Kirchherr *et al.*, 2018; McDowall *et al.*, 2017; Su *et al.*, 2013). Many of the initial CE business models (BMs) have created jobs and novel value for the companies that have adopted them (Boons *et al.*, 2012; Boons and Lüdeke-Freund, 2013; Ghisellini *et al.*, 2016; Vergragt, 2016). As such, circular business models (CBMs) have been generated by many companies in different industries to serve for the purposes of sustainable development while generating economic value. Despite the synergies between CBM and remanufacturing industry, the literature remains segregated and underdeveloped to present understanding of CBM generation in this specific industry by understanding the opportunities and barriers.

Besides being an industry *per se*, remanufacturing is also addressed as a strategy in companies' BM to achieve CE by slowing resource loops. Three strategies suggested by Bocken *et al.* (2016), are: slowing resource loops (repair or remanufacturing), closing resource loops (recycling or upcycling) and narrowing resource flows (resource efficiency). Slowing resource loops is considered relatively more viable than other strategies, given its potential impact. Accordingly, remanufacturing industry constitutes a strong lever to achieve CE. At present, the recycling rate of China's scrap steel and waste non-ferrous metals is only 10 and 25 percent, respectively, the US scrap utilization rate exceeds 50 percent, Japan's aluminum recycling rate exceeds 90 percent and the EU lead recycling cycle utilization rate exceeds 70 percent. Remanufacturing is an important direction for the development of China's manufacturing industry. In 2017, China's car ownership reached more than 170m vehicles, and about 5m vehicles were scrapped annually. It is estimated that by 2020, China's car ownership will exceed 200m, and the total number of scrapped cars will reach 12–16m. The number of scrapped vehicles are increasing year by year, which provides a lot of resources for the remanufacturing industry. In 2015, the output value of the remanufacturing industry reached 150bn yuan. In the "High-end Intelligent Remanufacturing Action Plan (2018–2020)," it proposed that China's remanufacturing industry will reach 200bn yuan by 2020. With the "13th Five-Year Plan" as a key project for the remanufacturing industry, China's remanufacturing industry is in the stage of comprehensive accelerated development.

A firm's BM is "the conceptual logic of how the firm creates and appropriates economic value" (Björkdahl, 2009, p. 1468). Having integrated sustainability aspects to BM, business model innovation refers to the methods used to promote sustainable forms of production and consumption, and is related to both technological innovations and the CE (Sarasini and Linder, 2018). Accordingly, a CBM can be understood as a class of or generic strategy for sustainable BMs (Geissdoerfer *et al.*, 2018). CBM has been defined as "a business model in which the conceptual logic for value creation is based on utilizing economic value retained in products after use in the production of new offerings" (Linder and Williander, 2017, p. 183). Therefore, CBMs emphasize a return flow to the producer from users, although there can be intermediaries between the two parties.

Most research on BMs has focused on value mapping and analysis. For instance, three systems for mapping the value dimensions of the BMs are as follows:

(1) value proposition and value delivery, financial structure (Linder and Cantrell, 2000);

(2) value proposition, value creation and delivery system, value capture (Bocken *et al.*, 2014; Richardson, 2008; Steffen *et al.*, 2015); and

(3) value proposition, value creation and value capture (Clauss, 2016).

Previous studies have developed a narrow taxonomy of CBMs based on the degree of circularity along two major dimensions: value creation: the value network which means the ways through which the company's interactions with suppliers and reorganizes its own internal activities; and value capture: the customer value proposition and interface, which is the circularity in value to customers (Urbinati *et al.*, 2017). Ünal *et al.* (2018) used this taxonomy to map a set of managerial practices for a CBM with circularity along three main dimensions: value network, customer value proposition and interface, and managerial commitment. They also considered the internal and external contextual factors relevant to creating value within a CBM (Ünal *et al.*, 2019; Urbinati *et al.*, 2018). Ranta *et al.* (2018) studied the components and subcomponents of BMs to determine how value was added in a CE BM. Nußholz (2018) proposed a CBM mapping tool for creating value by prolonging the lifespans of products and closing material loops. The tool offers a standardized representation of the elements and possible cycles of CBMs.

There have been many studies of the drivers of and barriers to CE implementation (Bouzon *et al.*, 2018; Zhu *et al.*, 2014). Previous studies have identified several drivers of CBMs, including policy and legal regulations (Sarasini and Linder, 2018), cost savings during manufacturing (Stahel, 2010), enhanced customer relations (Walsh, 2013), leadership in moving BMs toward greater sustainability (Rauter *et al.*, 2017), improved customer behavior understanding (Firnkorn and Müller, 2012), improved margins (Pearce, 2009a, b), reduced environmental impact (Mont, 2002), and organizational culture and increased brand protection (Seitz, 2007). Linder and Williander (2017) assessed the influence of several drivers of CE implementation, i.e., typologies of customers' needs, technological expertise of companies and portfolio of products. They also considered barriers such as operational risks and risks of cannibalization, fashion vulnerability, the tying up of capital and lack of incentives for partners. Other relevant drivers of sustainable BMs were legal regulations, leadership, organizational culture and coherence between firms' corporate strategies and a sustainable BM (Rauter *et al.*, 2017). A survey of 77 companies operating in the EU found that the implementation of CE-related practices was driven by economic rather than environmentally conscious behaviors (Masi *et al.*, 2018). For SMEs, companies' environmental culture (maximum, 67 percent), networking (33 percent), support from the demand network, financial attractiveness, recognition, personal knowledge and government support (minimum 4 percent) were the primary drivers. Most of the companies said that a proper mindset and the commitment of staff were also important aspects of the transition to a CE (Rizos *et al.*, 2016).

Studies have identified barriers to implementing a CE, including a lack of capital, lack of consumer interest and awareness, hesitant company culture (Kirchherr, Hekkert and Bour, 2017), lack of government support/effective legislation (Kumar *et al.*, 2019; Rizos *et al.*, 2016), lack of technical and technological know-how (Tukker, 2015), lack of support from supply and demand networks, and channel control (Linder and Williander, 2017; Rizos *et al.*, 2016). None of the studies identified technological barriers as among the most serious barriers to implementing a CE (Kirchherr, Hekkert and Bour, 2017). A recent doctoral thesis (Guldmann, 2019) categorized more than 30 sub-barriers to developing a CE into four types: institutional level, value chain level, organizational level and employee level. The author found that eco-design and internal environmental management practices have a medium level of implementation. Significant upfront investment costs and a lack of awareness or sense of urgency have been identified as barriers to CE implementation (Masi *et al.*, 2018).

In China, companies have a relatively good understanding of the nature and value of a CE. They are willing to operate a CE, but are not enthusiastically implementing the related strategies due to structural, cultural and contextual barriers (Liu and Bai, 2014). Although China can be considered an early adopter of CE, little is known about its implementation in the Chinese automobile parts remanufacturing industry. In particular, there is a need for empirical research in the following four areas:

(1) There is a lack of firm-level studies examining how firms adapt the alternative CE paradigm and transform their current BMs.

(2) There are not enough references or guidelines for building a viable CE BM for remanufacturing industry in line with the premises of CE. It is necessary to create a framework explaining how companies can adjust their existing BMs or create new ones.

(3) Given the BMs are a contingency phenomenon (Morris *et al.*, 2005), Chinese context provides certain peculiarities in terms of market dynamics, tensions, regulations and industrial capabilities for CBM generation, which is yet to be explored.

(4) In particular, Chinese remanufacturing BMs remain unexplored, and further theoretical and empirical research on how a CE is being implemented by companies is required.

Accordingly, this study investigates the CE BMs that have been implemented by two leading Chinese remanufacturing companies. It examines their strategies and tactics (STs) from the perspective of value network and customer value proposition and interface, respectively, and the development process of their BMs. We provide insights regarding the CBM transformation in remanufacturing industry and mapped the opportunities and barriers. Consequently, we contribute the theoretical understanding of CBM generation by consolidating and extending the existed theoretical framework.

The paper is organized as follows. In the following part (Section 2), we have provided the state of the art on CBM and remanufacturing industry. Later, we presented our method of a cross-case analysis approach and research model (Section 3). Section 4 provides the brief introduction of cases and the main findings in their BM development. Furthermore, strategy and tactical level of companies and CBMs dimensions are analyzed. In Section 5, the barriers and opportunities of remanufacturing industry are discussed. The implications for academics, scholars and policy makers, limitations of study and further research agenda are provided at the end of the paper.

2. Literature review

2.1 Circular business model

The CE concept is attracting worldwide interest as a solution to the environmental and other social and economic challenges of traditional linear manufacturing BMs (Ghisellini *et al.*, 2016; Garza-Reyes *et al.*, 2019). In a CE, production value chains are shifted from linear to circular manufacturing BMs (Garza-Reyes *et al.*, 2019). The CE is a general concept that can encompasses a range of sustainability practices (Ghisellini *et al.*, 2016), such as remanufacturing and "cradle-to-cradle" practices (Ünal and Shao, 2019). However, very little attention has been paid to the operationalization of CE principles and practices at the level of manufacturing systems and processes (Garza-Reyes *et al.*, 2019).

Kirchherr, Hekkert and Bour (2017), Kirchherr, Reike and Hekkert (2017) define CE as: "a circular economy describes an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso-level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations" (p. 224). In the same vein, Geissdoerfer *et al.* (2018) accentuate that: "circular business models are not only creating sustainable value, employing pro-active multi-stakeholder management, and have a long-term perspective, but also close, slow, intensify, de-materialize, and narrow resource loops" (p. 405). Accordingly, by its very nature, remanufacturing industry constitutes a proper platform for the realization of CBM as it can be leveraged as a strategy to slow the resource loops. Accordingly, we perceive the paradigms of remanufacturing and CE as BM challenge as they determine the rationale of doing business; in other world how the business functions.

2.2 Remanufacturing industry

Remanufactured products have been called refurbished, reconditioned, rebuilt or recertified (Abbey *et al.*, 2015; John and Sridharan, 2015). A remanufacturer disassembles and cleans a previously used product, then replaces or restores all of the missing, defective, worn or broken parts before reassembling and testing the rebuilt product to ensure that its operation is comparable to that of a similar new product (Lund, 1984). The product, now restored to "like new" condition, goes back into the market for resale (Guide and Wassenhove, 2001). Remanufacturing has been studied in many fields, including operations management (Guide and Wassenhove, 2001), strategy (Low and Ng, 2018), supply chain management (Chiarini, 2014; Zhu *et al.*, 2014), closed-loop supply chain management (Geissdoerfer *et al.*, 2018; Wang *et al.*, 2017), and innovation and BMs (Atasu *et al.*, 2008; Jia *et al.*, 2016). Recently, strategic management scholars have begun to examine remanufacturing as a BM, and have tried to define how value is created and captured in such systems.

Jia *et al.* (2016) suggested that the supply-demand imbalance made a strategic BM suitable for remanufacturing companies. John and Sridharan (2015) built a mathematical model of a multi-stage reverse supply chain. Nußholz (2018) developed a tool to build a standardized representation of the elements and possible cycles of CBMs, with the aim of prolonging the useful life of products and parts, and closing material loops.

Other studies have considered the various elements that are essential to remanufacturing BMs, such as sales force (Kovach *et al.*, 2018), consumer perceptions (Abbey *et al.*, 2015) and weak third party bargaining power (Wang *et al.*, 2017). In their study of bargaining in the remanufacturing industry, Wang *et al.* (2017) found that there were always parameter combinations under which profitability and environmental goals were in conflict. When the third party had limited bargaining power or the fixed cost for in-house remanufacturing was relatively high, the profitability and environmental goals were more likely to align. Kovach *et al.* (2018) used a sales force incentive model to analyze how sales force incentives influence a firm's remanufacturing strategy and profitability.

In their study of consumer perceptions of remanufactured consumer products in closed-loop supply chains, Abbey *et al.* (2015) found that discounting had a consistently positive, linear effect on remanufactured products' attractiveness. Moreover, when remanufactured products were presented to green consumers as green products, they typically found remanufactured products significantly more attractive (Abbey *et al.*, 2015). Michaud and Llerena (2011) used experimental auctions to show that willingness to pay is not necessarily lower for remanufactured products when environmental information is provided. Consumer interest and willingness to pay were found to be influenced by market barriers, which were induced by a lack of synergistic governmental interventions to accelerate the transition toward a CE (Kirchherr, Hekkert and Bour, 2017).

Consumer perceptions of remanufactured consumer products are a crucial component of sustainability in the remanufacturing industry (Shao *et al.*, 2016). Consumers consider green issues in their purchase decisions (Banytė *et al.*, 2010; Schlegelmilch *et al.*, 1996; Young *et al.*, 2010), and there is already an increasing demand for product-level sustainability information (Grunert *et al.*, 2014; Marucheck *et al.*, 2011). Consumers are demanding more information about products' supply chains and production history (Marucheck *et al.*, 2011), and are ready to pay a premium for a product that offers full transparency on such information (Owusu and Anifori, 2013; Xu *et al.*, 2012). A recent study showed that including environmental impact information had a significant influence on green purchasing decisions, but social impact information did not (Shao and Ünal, 2019). In other words, consumers do not consider a product's social sustainability performance in their purchase decision. If sustainability-related information is limited, consumers are not able to make informed choices (Caniato *et al.*, 2012; Lebel and Lorek, 2008; Meise *et al.*, 2014). Studies have found that consumers have a poor opinion of remanufactured products and are typically not prepared to buy them. Consumers' attitudes toward remanufactured products are an important moderating factor that predicts whether consumers will switch their purchasing behavior to remanufactured products (Hazen *et al.*, 2017). Thus, a lack of consumer interest and awareness and a hesitant company culture are considered the main barriers to a CE by businesses and policy makers (Kirchherr, Hekkert and Bour, 2017).

3. Research design and methods

3.1 Research design

This study used the framework developed by Urbinati *et al.* (2017) to conduct a case analysis of value networks, and customer value proposition and interface in CE BMs (see Figure 1). The value networks of two companies were evaluated according to the following characteristics: effective communications, awareness and new skills, EE-driven practices, environmental friendly material-driven practices, and DfX practices (design for recycling, design for remanufacturing and reuse, design for disassembly, design for environment). These criteria were grouped into three categories: energy efficiency, material use and DfX practices. When a company's BM was more aligned with the material use criteria or implemented one or more DfX, the circularity of the organization was considered higher.

The dimension of customer value proposition and interface includes price criteria (e.g. sale of single products, sale of products with assets/services, leasing/renting and pay-per-use) and promotion criteria (e.g. website promotion, in-store promotion, customer involvement in circularity initiatives and communication of circularity through all channels). When an

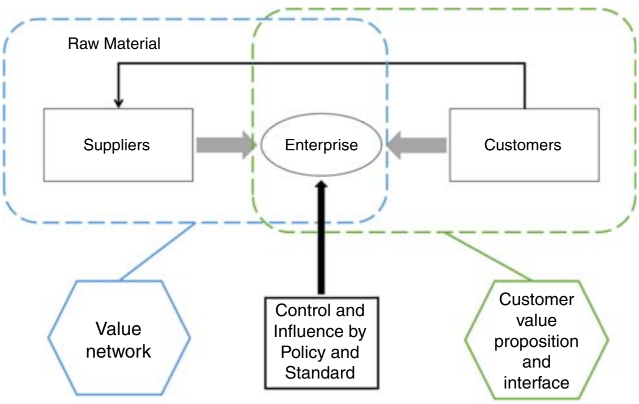

Figure 1.
Research model

organization's BM had more leasing/renting, pay-per-use, etc., characteristics, the circularity of the organization was considered higher. When the BM had stronger customer involvement and more communication about circularity, the circularity of the organization was considered higher (see Table I).

Furthermore, Garbie's (2017) analysis of the STs used by remanufacturers identified 15 STs that an industrial organization can use to implement sustainability. To study and understand the roles of both value networks and customer value proposition and interface in CBMs, this study used a cross-case analysis approach to conduct an in-depth analysis of the STs used in remanufacturing BMs (Garbie, 2017). These STs were as follows: ST1 – literacy in sustainability with commitment from stakeholders; ST2 – globalization and international issues; ST3 – innovative product design; ST4 – designing/reconfiguring manufacturing enterprises; ST5 – lack of accountability (organization performance); ST6 – liquidity in organizational management; ST7 – competitive manufacturing strategies; ST8 – standardized workplace; ST9 – follow-up on human rights procedures; ST10 – follow-up on customer and business practice issues; ST11 – natural environment management; ST12 – consumption of natural resources; ST13 – preventing pollution and environmental impacts; ST14 – drivers and motivators within enterprises; and ST15 – understanding barriers within enterprises.

Accordingly, a cross-case study was conducted by in-depth examining on relevant strategy and tactical measures. The study focused on the following research questions:

RQ1. What strategic and tactical measures do companies implement to support the value network in their CBMs?

RQ2. What strategic and tactical measures do companies implement to support customer value proposition and interface in their CBMs?

RQ3. What are the opportunities and barriers for CBM generation in remanufacturing industry?

3.2 Methods

Case studies collect data from archival materials, interviews, observations, etc. An in-depth case study asks "what" a phenomenon is and "why" and "how" it occurs (Yin, 2017). This study explored the CBMs of China's automobile remanufacturing industry using the cross-case study method. Cross-case analysis is a qualitative and systematic method suitable for the study of small samples, and it is simple and easy to operate. Focusing on two enterprises that are representative of China's automotive parts remanufacturing industry, this study collected data from archives, interviews and observations. The results will help policy makers to formulate better and more targeted interventions to promote a CE. Although many international organizations have used qualitative research to support projects and programs, it has limitations. Due to the small

Table I. Characteristics of value networks and customer value proposition and interface

Value network	Customer value proposition and interface
Effective communication	Sale of single products
Awareness and new skills	Sale of products with assets/services
EE-driven practices	Leasing/renting
Environmental friendly material-driven practices	Pay-per-use
DfX-Design for recycling	Website promotion
DfX-Design for remanufacturing and reuse	In-store promotion
DfX-Design for disassembly	Customer involvement in circularity initiatives
DfX-Design for environment	Communication about circularity through all channels

Source: Urbinati *et al.* (2017)

sample size, it may not capture the broader picture. Despite this, the results of this study make theoretical contributions to the understanding of CBMs and reveal some of the obstacles and opportunities in the remanufacturing industry. The results can inform policy development.

This study focused on the development and innovation of the CBM in the auto parts remanufacturing industry. First, to ensure that we understood the development of the domestic remanufacturing industry, we collected and categorized national policies and industry standards for remanufacturing. In total, 14 auto parts remanufacturing pilot enterprises were launched by the National Development and Reform Commission in 2008, and a further 28 were launched in 2013.

To ensure that the companies selected for the case studies were representative of these pilot companies, we considered their scale and technology, market share, conduciveness to sustainable remanufacturing practices, and social influence and media exposure before choosing Company A and Company B for our cross-case exploratory research. The predecessor of Company A (a joint venture company) was one of the first auto parts remanufacturing enterprises in China. Company A was launched as one of the second wave of auto parts remanufacturers. The parent company of Company A was among the world's top 500 machinery enterprises and China's top 100 machinery brands. Company B was the first automobile engine remanufacturer in China. The parent company of Company B was the leading heavy-duty automobile enterprise in China.

Companies A and B were leaders in China's auto parts remanufacturing industry. Both companies were representatives of China's auto parts remanufacturing industry at the China National People's Congress press conference (to which four companies sent representatives), where they gave interviews with Chinese and foreign media. They also participated in developing national standards for remanufacturing, the CE, sustainable development and emissions of automobile pollutants. Moreover, the parent companies of the two companies were leaders in automotive engine manufacturing in China. Both Company A and Company B were benchmark enterprises in China's automotive parts remanufacturing industry.

Through the cross-case research, the study will explore the CBM of these two companies, summarize the current obstacles, and predict the future direction and opportunities of the automotive parts remanufacturing industry. It will also help managers to design viable CBMs in a different context of companies and contribute to the CBM literature.

This study collected data on remanufactured products, including the quantity of recycled parts used, the output of remanufactured products, the sales volume of remanufactured products and profits. The data on the companies included the number of employees, the area covered, the amount of marketing and the number of people involved. Data on the companies' technology and development included remanufacturing capabilities, product categories, technological innovation and development levels, and the processes used to manage and remanufacture used components. Data on the CE and environmental protection included the energy saved and emission reduction capacity of the remanufacturing process, with variables such as water saved, energy (coal, electric energy, etc.) and materials saved, and a reduction in emissions of pollutants such as CO_2 and solid waste.

To collect data on all of these variables, the study used primary and secondary sources. The primary sources included: semi-structured, on-the-spot interviews, listening to reports, seminars, etc., with sales general managers and technical department managers (these data are recorded and partially compiled into documents for review); and inspections of the plant with the general managers.

The semi-structured interview questions were divided into four topics. First, background-technology and products. The first set of questions explored the technology adopted by the company, particularly the introduction and innovation of remanufacturing technology, and the production processes. Second, value network. The second set of questions asked about the companies' sales processes (pre-sales and after-sales, etc.), the partnership and business positioning in the supply chain, and what kind of customers the company targeted. Third, customer value proposition and interface. The third set of questions explored the contributions of remanufactured products to society, market sales and the public recognition of remanufactured products. Fourth, future prospects. The final set of questions asked about the future plans for the company and forecasts for future markets. The semi-structured interview questions are provided in Table AI.

The interviews were conducted on site at the two companies. The information about the interviews is summarized in Table II. At Company A, we listened to the general manager's report on the company and conducted semi-structured on-the-spot interviews with the general manager and technical director. The meeting lasted for about 2 h and was followed by a discussion that lasted about 1 h. Relevant notes, videos and interview recordings were collected and saved for further analysis. Finally, under the leadership of the general manager, we visited the company's production workshop to better understand the company's production process.

At Company B, we visited the company's exhibition hall accompanied by the technical director and sales manager, learned about its development process, and conducted a semi-structured on-the-spot interview with the two individuals. The meeting lasted about two-and-a-half hours. Finally, we visited the company's key laboratory to collect some more detailed information. Due to confidentiality and some other reasons, we were only able to collect some of the data we required, as well as some reports and publicity documents. We received strong support and timely responses from the companies through e-mail and other communication tools when we sought updates and follow-up data.

Our secondary sources of data included: major published articles about the companies and selected articles on the industry or related topics; documents obtained directly from the companies, including books, articles, speeches, internal newspapers, websites and annual seminars; and annual reports, agency statements, analyst reports and other relevant company materials. After data collection, we analyzed and organized the data and identified the themes. We then extracted the BMs that underpinned the companies' business process. Finally, we summarized the current development opportunities and obstacles in the automotive parts remanufacturing industry.

Company	Company A	Company B
Location	Suzhou, Jiangsu, China	Jinan, Shandong, China
Interviewees	General manager Technical director	Technical director Sales manager
Number and duration of interviews	Two interviews lasting over 3 h One company visit, manufacturing site visit, observations, informal interactions (over 6 h)	Two interviews for about two-and-a-half hours One company visit, manufacturing site visit, observations, informal interactions (over 5 h)
Secondary sources	Firm website, brochures, audio materials (general manager's talk), documents shared by company	Firm website, brochures, audio materials (sales manager's talk), reports shared by the company
Number of employees	150	1,300
Industry	Remanufacturing of automotive parts	Remanufacturing of automotive parts
Founding year	2010	1994
Products	Remanufactured engines, remanufactured body assemblies and engine parts	S-type remanufactured engine, remanufacturing base machines, remanufactured body assemblies and engine parts

Table II.
Company information

4. Results

4.1 Case introduction

This section presents the preliminary findings for each company in terms of sales indicators, BM evolution, remanufacturing figures, etc.

4.1.1 Company A. Company A was a wholly owned subsidiary of a Chinese engine manufacturing company. The company was located in Suzhou Industrial Park and provided remanufacturing services for the parent company's engines and auto parts. The company had a total investment of $50m and covered an area of about 60,000 m^2. It had years of international remanufacturing experience and a well-established remanufacturing technology platform. It had many technologically advanced remanufacturing production lines for remanufacturing engines, basic machines, airframes, crankshafts and cylinder heads. The company's products included diesel engines and auto parts distributed in the aftermarket of the parent company. The aims of Company A's innovative service model were "reducing social costs, developing a circular economy, and building green power." It was committed to promoting effective practices in a CE through low-carbon economic development and cost-effective products and service choices for the market.

The development of Company A's auto parts remanufacturing process can be roughly divided into three stages: preliminary (2004–2008); construction and development (2009–2014); and rapid development (2015–present). At the beginning of the twenty-first century, the concept of remanufacturing was introduced into China. In 2004, the parent company of Company A began research on automotive parts remanufacturing. In early 2006, after two years of domestic and international investigations, the parent company announced a new strategy "Green development, harmonious and win-win," and then promoted it as a core element of the enterprise. In 2008, Company A became one of the first pilot companies in China to remanufacture automotive parts, ending the preliminary stage and entering the construction and development stage. The company was located in Suzhou Industrial Park. In July 2012, a new plant was put into operation, and the company's remanufacturing capacity continued to expand and improve, as planned. In 2013, the joint venture company became part of the second wave of auto parts remanufacturing enterprises. This company has posted losses in every year since 2013. In 2014, the foreign-funded company withdrew its capital. The parent company purchased all of the shares to achieve full control and established its current subsidiary company.

In the third phase, Company A began to change its BM, focusing on reclaiming high-quality used engines and cooperating with large customers such as bus passenger transport companies. The company's performance began to improve, but the losses continued. In 2017, Company A decided not to reclaim used engines from a wide range of customers, but to restrict its customers to large companies and adopt the parent company's three-guarantees returns policy. The company began to make profits, and its development seemed on the right track. As of 2019, the company had 120–150 employees, with few fluctuations, and most of the production line has been automated. The parent company has a market share of 2.5m engines, and more than 500,000 of its engines enter the market every year. In addition, 2 percent of the engines, that is 50,000, are used, which may become market opportunities for Company A in the future. The details on Company A's remanufacturing output are shown in Table III. The evolution of Company A's BM is outlined in Table AII.

Years	Number of engines remanufactured	Amount (yuan, excluding tax)
2015	1,221	1.85m
2016	2,039	2.98m
2017	1,361	1.31m
Total	4,621	6.14m

Table III. Remanufactured engines in Company A

4.1.2 Company B. Founded in 1994, Company B was the first domestic enterprise to specialize in automobile engine remanufacturing. It was established by its parent company to expand its corporate social responsibility. The company covered an area of 73,000 square meters and had more than 1,300 employees. In October 2005, it was designated the first demonstration unit of the national CE by six ministries and commissions (National Development and Reform Commission, State Environmental Protection Administration, Ministry of Science and Technology, Ministry of Finance, Ministry of Commerce and National Statistical Bureau).

Since its founding, Company B has manufactured automotive parts and remanufactured engines from Europe and the USA. It had a mature production line with the highest level of domestic technology for processing automotive parts and remanufacturing engines and spare parts. It also established a specialized, modern and internationalized system of technology, production, supply and marketing based on a modern enterprise management system. The remanufactured products mainly consisted of remanufactured S-type engines and their components. It was a professional engine remanufacturing enterprise with a high resource use rate and the capacity to produce 20,000 remanufactured engines.

As part of the pilot CE program for the remanufacture of automotive parts, Company B focused on solving the technical and equipment bottlenecks that restricted engine remanufacturing output and on improving the quality of the products and of the remanufacturing and processing of waste engines. They fully exploited the added value of resources, materials and labor in the used engines, creating obvious economic, resource and environmental benefits. They set an example for China's engine remanufacturing industry, and provided useful feedback for building a CE. While accumulating experience in the industrialization of auto parts remanufacturing in China, Company B adhered to the philosophy of "creating high-quality products with high-quality personality and providing society with high-quality products." They developed and innovated processes and made continuous efforts to provide customers with high-quality, cost-effective products and to promote the development of China's engine and automotive parts remanufacturing industry.

4.2 Analysis of the circular business model

Combining the characteristics of the BMs of the two companies discussed above, this study established a four-part BM for the automobile parts remanufacturing industry: reclaiming raw materials, managing the used components, developing and implementing production technology and processes, and marketing.

4.2.1 Reclaiming raw materials. Company A recovered used machines and parts as raw materials for the whole society at the beginning, but the quality of the used machines and parts of individual scattered customers was poor, and the recycling value of remanufacturing was not high. Therefore, it began to cooperate with major customers such as public transportation and quality-guaranteed return project of the parent company to recover high-quality used parts, so that the models of remanufactured products tend to be fixed, the supply of raw materials is more stable, and the production process is more perfect.

Company B implemented a reverse logistics model called "Used-for-Remanufacturing." This was "a model of reclaiming from product purchasers used machines (pieces) that can be applied to remanufacturing, and selling remanufactured products at replacement prices." This mechanism greatly improved the recovery rate of used machines and parts, and allowed the company to evaluate the state of the used machine, and therefore set an appropriate exchange price. In this way, according to the interviewee, "the reclamation source of the used machine is guaranteed, and when selling the remanufactured engine, the enthusiasm of the user for purchasing the remanufactured engine increases."

Second, by continuously "strengthening the information component of the after-sales service of the parent company, and gradually incorporating the remanufactured engine into the after-sales service network," the problems of engine sales and raw material recycling were solved. Thus, Company B achieved early success by cultivating the engine remanufacturing market. As of August 2013, more than 200 agents had signed an agency agreement with Company B, and this was a good foundation for the further development of the market.

4.2.2 Managing used components. Given the large quantity, large variety and difficult management of waste engines, the companies needed to establish "a system and model that can provide visual information for raw material requirements." Based on the existing enterprise resource planning production management systems and drawing lessons from foreign enterprise resource planning management, both companies focused on improving the processes for reclaiming used machines, managing inventory and improving sales by developing a model for the logistics information management of engine remanufacturing. Establishing a batch inventory model for the flow of materials and classification of used machine disassembly processes and parts, including returned products, requires a full account of raw material matching restrictions and strategies, the formulation of remanufacturing processes and remanufacturing standards, and the development of strict control standards to ensure the quantity, quality and timeliness of the remanufactured products. Company B's logistics demand plan needed to keep track of not only the temporary stock consisting of raw materials, semi-finished products and components, but also the inventory of the same products at various stages of disassembly and the finished products.

As the manager of Company B explained, to avoid long wait times for users seeking to replace remanufactured products with used machines, "we introduced the 'fixed-price' management, that is, we pre-judged the state of the whole machine and fixed the price on the spot." This significantly shortened the time needed to calculate the added value after disassembly of the used machines, but increased the requirements for the professional judgment of the salespeople. An advanced information and inventory management system can help a company to effectively classify and manage diverse types of used engines with a variety of damage, effectively guide production, reduce costs and improve production management efficiency.

4.2.3 Production technology and process. According to the manager in Company A, "the remanufacturing and repairing technology has relied mainly on foreign companies' remanufacturing experience for more than 30 years." The company has developed a remanufacturing technology platform over many years that includes a partial recasting technology for cast parts, arc spraying technology, cold spraying technology, internal hole spraying technology, laser cladding technology, thin film coating technology, non-destructive testing technology and repair process verification. These repair techniques have been automated, but disassembly, cleaning and inspection still require manual operators.

Unlike Company A, the manager of Company B said that "we cooperated with research institutions to independently develop remanufacturing technologies." Company B received funding from the "11th and 12th Five-Year" National Science and Technology Support Program, the Armored Forces Engineering College of the Chinese People's Liberation Army and other sources. In recent years, with the strong support of the National Development and Reform Commission, Company B achieved rapid development in remanufacturing with remarkable results.

Company B gradually advanced "green dismantling and environmentally friendly clean production technology; has the means of restoring machining parts such as engine blocks, cylinder heads, crankshafts, camshafts, and connecting rods; has the surface engineering processing methods at the leading edge of technology at home and abroad; has an inventory information management method for remanufactured engine parts and remanufacturing processes." The remanufactured products gradually developed into a series of high-value remanufactured products such as automotive engines, engineering machinery engines, marine engines, upgraded special engines, air compressors, injectors and oil pumps.

According to the manager in Company B, "for remanufactured engines, a disassembly-cleaning-inspection-repair-assembly-test-run-packaging process is mainly adopted." The detailed process is shown in Figure 2. The remanufacturing process for engine components was consistent with the production requirements of the original automobile parts, and there were some similarities in the processes. The remanufacturing process started with reclaiming materials, but there was a certain loss rate in automobile reclaiming, related to the specific requirements for original parts, before the fundamental processes of cleaning, disassembly, monitoring, classification and so on were carried out.

The manager of Company B said that "According to statistical analysis, the production cycle of remanufacturing an engine is half as long as that of a new engine." Furthermore, 94 percent of the metal of the original product can be reused, and the selling price is about a third of that of the new product.

"Through advanced remanufacturing equipment, advanced production processes, and strict quality control procedures, Company A ensures that products meet design standards." Remanufactured products can save 50 percent of the costs and reduce greenhouse gas emissions by 61 percent compared with the manufacture of new products. Remanufactured products with the same quality, performance, lifespan and warranty service as new products can be produced with only 7 percent of the water, 14 percent of the energy and 30 percent of the raw materials, while producing almost no solid waste.

As mentioned above, through a combination of industry, education and research, and exploration and innovation, "Company B applies advanced remanufacturing key technologies," such as its self-developed advanced surface engineering, non-destructive testing and residual life assessment, to its remanufacturing production, which dramatically improved the quality of the remanufactured products. The extensive application of remanufacturing surface engineering technology further enhanced the utilization rate of used components, and more than 80 percent of the used components were remanufactured.

With the application of key technologies, "the effect of energy saving and emission reduction in Company B is remarkable." Compared with recycling used machines, the production of every 10,000 remanufactured engines saved 4,250 tons of material and 10.34m kWh of energy (equivalent to 4,924.4 tons of standard coal). The recycling efficiency of renewable resources (scrap iron and steel, non-ferrous metals, paper, plastics, rubber) increased by 21.65 percent; carbon dioxide emissions were reduced by 10,447.5 tons, cost savings were 50 percent, material savings were 70 percent and energy saving were more than 60 percent.

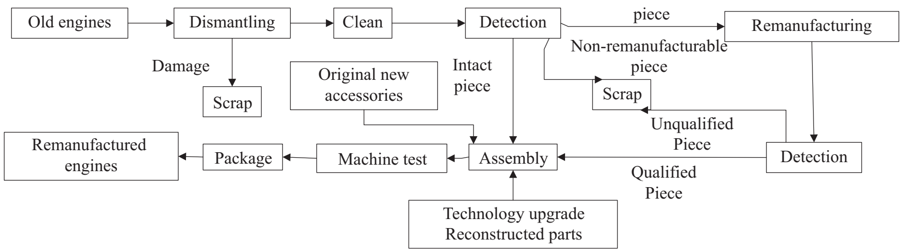

Figure 2. Company B's remanufacturing process

4.2.4 Marketing. From the value mapping perspective, as the parent company of Company A made a variety of engines, the subsidiary's remanufacturing services could not supply all of the parent company's product types. Therefore, Company A specialized in particular remanufactured products including whole machines with partially remanufactured parts, customized base machines, remanufactured base machines, remanufactured body assemblies and engine parts. The base machine did not include peripheral components, and usually only included a cylinder block, cylinder head, crankshaft, camshaft, connecting rod, piston, fuel injector, idler gear assembly and other accessories. A body assembly was an assembling product with a crankshaft, a connecting rod, a piston, a cylinder liner, a camshaft, etc. To meet the complex market demands, the remanufactured base machines and body assemblies were the main products manufactured and sold by the company. They were mainly used in the after-sale maintenance service market and sold through specific stores.

Managers in both companies mentioned that participating in the exchanges of "used engines for remanufactured" engines had the following advantages:

(1) Cost: according to the maintenance cost control requirements, the customized base machine (without peripheral assembly parts) was the leading product, and the product price was close to or equal to the customer's own maintenance cost (manual+material+downtime standby).

(2) Quality: the product performance, reliability and quality was better than the customer's self-repair.

(3) Time: the time needed to overhaul a single unit was eliminated, and batch overhauls saved on human resources and equipment investment.

(4) Assurance: the replacement of the customized base machine came with a three-guarantees service guarantee for one year, and the engine enjoyed the same warranty mileage as a new machine from the parent company.

For some key and high-quality customers, Company A "adopted a customized method of remanufacturing products to reduce costs, improve work efficiency, and provide greater use value for customers." Taking the bus transportation clients as an example, as the bus transportation operator repaired and maintained its engines on schedule and the committed operation violations less often, the quality of the used engines they provided Company A with was relatively high. Company A communicated with the bus transportation company and prepared the remanufactured engines in advance. When the bus transportation company had a need, Company A could directly sell the remanufactured products to them, while reclaiming the used engines. This efficiently saved the customer's time, and also protected Company A's source of used engines. This system was efficient for both customers and remanufacturers, as shown in Figure 3.

In accordance with the principle of "scattered reclaiming, centralized distribution, and use of specifications," Company B "actively promoted the construction of reverse logistics systems" (Manager). In addition to its "used-for-remanufacture pricing mechanism," the company "explored a reverse logistics system that was in line with China's national conditions, such as the 4S shop system." At the same time, under the influence of a new round of information technology, the company implemented an "internet+remanufacturing" action plan that used the internet to accelerate the establishment of a standardized and orderly reverse logistics system. The company divided the reverse logistics management into steps: reclaiming management, preliminary inspection, packaging and transportation, finished product distribution, and directed tracking. When all of the segments were connected, it became a closed-loop supply chain of products that combine reverse logistics and forward logistics.

Figure 3.
"Used-remanufactured" cycle model

In 2015, to achieve steady growth in the sale of remanufactured products, Company B focused on "improving sales" and developed a "backbone marketing network." The strategy was to continuously strengthen the development of marketing networks and marketing services, and steadily improve the quality of the marketing networks:

(1) To develop marketing networks, the company "optimized three aspects of the marketing network to expand marketing channels and expand market share." First, in the regions with mature networks, the marketing network was refined and strengthened, and more emphasis was placed on the development of independent distribution networks, especially brand franchise stores. Second, the evaluation of the coverage capability of the members of the marketing network was strengthened, and the construction of outlets in "blind and blank areas" was increased. Third, sales were optimized through a mechanism of member addition, promotion, categorization and elimination.

(2) To improve marketing services, Company B strengthened the integration platform of the inventory management system based on a "supply-sale-storage-after-sales service" model. This not only included the automated processing of storage and outbound data, various documents and statements of products and reduced the number of mistakes caused by human error, but also realized the sales management in different categories, sub-attributes and batches. The system platform also allowed information sharing. Users and suppliers could intuitively grasp the inventory information and delivery progress and perform real-time evaluations of the after-sales service personnel. The company was for the first time able to answer the customers' after-sales service questions through the platform, saving the cost of a telephone call, shortening the response time and achieving a direct dialogue with the user.

(3) To improve market promotion, Company B "launched a WeChat public marketing platform and synchronized the platform with the company's website" (manager). Users received timely information on the latest developments in the remanufacturing industry and the company through announcements on WeChat, as well as information about engine maintenance, vehicle maintenance, etc. Users could also directly access the company's product information on the company's website through their WeChat, enhancing users' experience and attracting more potential customers.

Automotive parts remanufacturing is a cyclic process, in which every link is indispensable. The above case studies show that enterprises currently have the capacity to remanufacture more automotive parts, but more customers are needed to enhance the growth of the industry.

4.3 Results on the strategy and tactical level of companies and circular business models dimensions

Based on the description in the section above, 15 STs of Company A and Company B are summarized in Table IV. The differences in their commitment to sustainability, innovative product/service designs and related designing/reconfiguring manufacturing processes are summarized. Furthermore, the degree of circularity in their value networks and customer value proposition and interface are compared in Table V.

There are several important differences between the two companies' customer value proposition and interface:

(1) Although Company A implemented an innovative service model/customized method, Company B had much more innovative product/service designs. Not only did Company B use the "supply-sale-storage-after-sales service" philosophy to extend the service of "relatives" among users, it also developed the "4S shop system/used-for-remanufactured item pricing mechanism" and "fixed-price" management, and used "internet+remanufacturing" to develop the WeChat public marketing platform. All of the practices brought significant strategic advantages to Company B. These practices also helped Company B to achieve a strong level of circularity in the domains of sale of products with assets/services. Company A achieved only a medium/strong level of circularity in terms of sale of products with assets/services. There was no evidence of leasing/renting or pay-per-use in the BMs of either company.

(2) In terms of competitive manufacturing strategies, Company A adjusted its business strategy by first reclaiming the used engines of individual customers and then shifting to exclusive arrangements with big customers and the parent company's returns products with three-guarantees. In contrast, Company B cooperated with universities, research institutes and other scientific research institutions to develop advanced clean production technology and an integrated platform for its inventory management system. It also developed a series of high-value remanufactured products. Together, these practices led to a high level of productivity and large market share. Company A has a production capacity of 15,000 remanufactured products per year, whereas Company B has a capacity of 20,000 remanufactured engines per year. However, Company A only produces 1,500 pieces/per year, whereas Company B remanufactures 4,000 engines/per year.

(3) Both companies have adopted customer and business follow-up practices. Company A has a customized follow-up method that provides greater use value for customers, and it has an arrangement with a bus transportation company that allows it to prepare the remanufactured engines in advance. Company B has a special maintenance station for its after-sales service, which provides an extended service to the "relatives" of users. It also maintains contact with users through its supply-sale-storage-after-sales service and WeChat public marketing platform. Both companies have strong levels of customer involvement in their circularity initiatives; however, some specific practices helped Company B to achieve a medium/strong level of circularity in communication through all channels, whereas Company A only achieved a medium level of circularity.

Strategies and tactics (STs)	Company A	Company B
ST1 – literacy in sustainability with commitment from stakeholders	Innovative service model/reducing social costs/developing CE/building green power	Creating high-quality products with high-quality personalities and providing society with high-quality products
ST2 – globalization and international issues	Establishing joint ventures in cooperation with foreign-funded enterprises	Receiving raw materials from Europe and the USA
ST3 – innovative product design	Innovative service model/customized method	Extending service to "relatives" of users/4S shop system/used-for-remanufacture pricing mechanism "fixed-price" management/"internet +remanufacturing"/supply-sale-storage-after-sales service/WeChat public marketing platform
ST4 – designing/reconfiguring manufacturing enterprises	Adjusted business strategy – no longer reclaiming used engines of individual customers/using engine exchanges for remanufactured engines	Modern enterprise management system/improving the remanufacturing and processing system of waste engines/self-developed advanced surface engineering/non-destructive testing and residual life assessment/"internet +remanufacturing"/closed-loop supply chain/development of an integration platform for the inventory management system
ST5 – lack of accountability (organization performance)	Not clear	Not clear
ST6 – liquidity in organizational management	Cooperates with bus companies and develop closed-loop supply chain	More than 200 agents signed an agreement with the company/closed-loop supply chain/development of integration platform for the inventory management system
ST7 – competitive manufacturing strategies	Adjusted business strategy – no longer reclaiming used engines of individual customers	Cooperating with universities, research institutes and other scientific research institutions/advancing clean production technology/inventory information management/developing into a series of high-value remanufactured products/"internet +remanufacturing"/integrating platform development of the inventory management system
ST8 – standardized workplace	Lean production	Establishing a standardized and orderly reverse logistics system
ST9 – follow-up on human rights procedures	Not clear	Creating high-quality products with high-quality personalities and providing society with high-quality products
ST10 – follow-up on customer and business practice issues	Customized method provides greater use value for customers/cooperates with bus transportation company and prepares the remanufactured engines in advance	Special maintenance station for its after-sales service-extended service to "relatives" of users/supply-sale-storage-after-sales service/WeChat public marketing platform

(*continued*)

Table IV.
Comparison of strategies and tactics

Strategies and tactics (STs)	Company A	Company B
ST11 – natural environment management	No solid waste	Advancing the "green" dismantling and environmentally friendly clean production technology/recycling efficiency of renewable resources increased by 21.65%
ST12 – consumption of natural resources	New products can be produced with only 7% of the water, 14% of the energy, and 30% of the raw materials	Every 10,000 remanufacturing engines could save 4,250 tons of material, and 10.34m kWh (equivalent to 4,924.4 tons of standard coal) every 10,1000 engines
ST13 – preventing pollution and environmental impacts	Remanufactured products can reduce greenhouse gas emissions by 61%	Advancing "green" dismantling and environmentally friendly clean production technology/surface engineering processing methods at the leading edge of technology/carbon dioxide emissions reduced by 10,447.5 tons every 10,1000 engines
ST14 – drivers and motivators within enterprises	Not clear	Continuously strengthening information construction/continuously developing marketing networks and marketing services
ST15 – understanding barriers within enterprises	Establishing a system and model that can provide visual information for raw material requirements/a batch inventory model for material flow registration and classification management of used machine disassembly, including returned products	Establishing a system and model that can provide visual information for raw material requirements/considering not only the temporary inventory of raw materials, semi-finished products and parts, but also the inventory of the same products, products in the process of disassembly, and finished products produced by remanufacturing

Table IV.

Value network	A	B	Customer value proposition and interface	A	B
Effective communications	Weak	Strong	Sale of single products	Medium	Medium
Awareness and new skills	Medium/strong	Strong	Sale of products with assets/services	Medium/strong	Strong
EE-driven practices	Strong	Strong	Leasing/renting	Weak	Weak
Environmental friendly material-driven practices	Strong	Strong	Pay-per-use	Weak	Weak
DfX-design for recycling	Strong	Strong	Website promotion	Medium	Medium
DfX-design for remanufacturing and reuse	Medium/strong	Strong	In-store promotion	Medium	Medium
DfX-design for disassembly	Medium/strong	Medium	Customer involvement in circularity initiatives	Strong	Strong
DfX-design for environment	Medium/strong	Strong	Communication of circularity through all channels	Weak	Medium/strong

Table V. Comparison of dimensions on value network and customer value proposition and interface

In terms of the value network, both companies managed the natural environment, decreased the consumption of natural resources, and reduced pollution and environmental impacts. The related EE-driven practices and environmentally friendly material-driven practices are strong in both cases. Furthermore, both companies have developed new techniques and management systems to help achieve higher levels of design for recycling, design for remanufacturing and reuse, design for disassembly and design for the environment. Company B has a slightly higher level of development in these areas due to its more effective methods and platforms.

5. Discussion

5.1 Barriers and opportunities

5.1.1 Barriers. There are still many obstacles to the development of the automobile parts remanufacturing industry. As shown in Table VI, the trend in the production and sales of remanufactured engines is downward for Company B. The two main reasons for this trend are as follows. First, due to the national policy and the emission standards upgrades for motor vehicles, many vehicles that have reached the overhaul stage do not participate in the remanufacturing process because they do not meet current emission standards. Second, by-products and disassembled parts are becoming more and more common in the market and are squeezing the remanufacturing market. Most customers prefer low-cost solutions, which limits their willingness to participate in the engine remanufacturing cycle. Drawing on the analysis of Company A and Company B, the main problems and obstacles are discussed in more detail in the following section.

5.1.2 Uncertainty of the overall development of remanufacturing industries. First, the overall development of the remanufacturing sector is very unclear. Previous studies have only considered whether public procurement policies are sustainability oriented (Kuo *et al.*, 2010; Rizos *et al.*, 2016), and it takes time to build new partnerships and mutual trust (Riisgaard *et al.*, 2016; Sabbaghi *et al.*, 2017). Furthermore, as there is currently no national remanufacturing industry development plan, the progress and direction of the remanufacturing sector varies from place to place. Some remanufacturing enterprises have not properly considered the relationship between the production of new products and remanufactured products. They have not analyzed important factors, such as the conditions of used parts and national sales channels. They have adopted foreign technologies and have not developed remanufacturing processes based on the mature technologies within the Chinese system.

Moreover, although some companies have started to apply DfX practices, the development plans of local governments and enterprises are not connected, and this has caused some contradictions and conflicts. Although many studies have discussed regulatory barriers to remanufacturing (Kissling *et al.*, 2013; Milovantseva and Fitzpatrick, 2015; Singh and Ordoñez, 2016; Stahel, 2010) and the uncertainty of legislation in this field (Kindström and Kowalkowski, 2014; Rizos *et al.*, 2016), there has been little research on the conflicts between the development plans of local governments and enterprises in this area. At present, few enterprises have visible remanufacturing characteristics, and there are few Chinese remanufacturing models that prioritize energy saving and material saving. Therefore, industrial development plans to regulate and guide this emerging industry are urgently needed. For example, the national motor vehicle pollutant emission standard has been continuously upgraded and has significantly changed over time, which means that many engines cannot be remanufactured, due to non-compliance with the new emission standards. This is very detrimental to the development of the automotive remanufacturing industry.

Table VI. Production and sales of remanufactured engines in Company B

Year	2014	2015	2016	2017
Production and sales volume	6,120	4,800	4,200	4,000

Second, we note that there are a lack of permission and evaluation mechanisms for market access, and the market is relatively chaotic. The entry of unqualified refurbished products into the after-sales service market as new parts not only affects the sales of conventional remanufactured products, but also means that real remanufacturing enterprises have no competitive advantage in the recycling used parts, which makes it difficult to recycle.

Third, remanufacturing standards are not perfect. Other studies have mentioned the lack of in-house resources, knowledge and competencies in this area (Besch, 2005; Linder and Williander, 2017; Ravi and Shankar, 2005; Rizos *et al.*, 2016; Sauvé *et al.*, 2015; Urbinati *et al.*, 2017). Some companies believe that manufacturing standards can be simply applied to remanufactured product and production standards, and they do not fully realize the complexity of the remanufacturing processes. Due to the lack of national rules and norms, most enterprises have not established quality control systems in critical parts of the remanufacturing process, such as used parts inspection and rough remanufactured repair, and the quality of remanufactured products is not empirically guaranteed.

5.1.3 Policy barriers and insufficient government support. Our analysis suggests that although the "Five-Year" National Science and Technology Support Program provided strong support for the remanufacturing industry, allowing some companies to achieve rapid development with remarkable results, the imperfect and frequently changing governmental policies have had a strong negative impact on the development of remanufacturing enterprises. This is the biggest obstacle to the development of automobile parts remanufacturing enterprises. This finding is consistent with the conclusions of Kumar *et al.* (2019), who identified legal barriers, poor enforcement of legislation and the lack of policy support as key barriers, followed by ineffective recycling policies and current tax regulations.

The frequent changes in governmental policies have had a strong impact on the development of remanufacturing enterprises. As the remanufacturing industry is still in the exploratory stage of development, many enterprises are in a wait-and-see mode. This leads to limited investment in remanufacturing enterprises, and modest development. There is little evidence that CBMs provide enterprises with financial and environmental benefits (Adams *et al.*, 2017; Mont, 2002), and accordingly, it is difficult to secure funding for these models.

The lack of relevant policies severely limits the development of remanufacturing. First, sourcing used parts is difficult in the absence of a national policy. The State Council Decree 307 "Measures for the Administration of Recycling Waste Vehicles" stipulates that "five assemblies" such as dismantled engines, transmission, front axles, rear axles and frames should be melted down for "scrap metal." Accordingly, pilot companies cannot use parts from scrapped cars in remanufacturing. They can only recover parts from their service network, which limits their development.

Second, the relevant tax policy has made it difficult for enterprises to offset VAT. In China's used parts market, the used parts purchased by remanufacturing enterprises from customers cannot be issued value-added input tax invoices, so they cannot be deducted, and the remaining tax rate is relatively high. Although the social benefits of remanufactured products are far superior to those of refurbished products, the preferential policies given to refurbished products are not yet applicable to remanufactured products, resulting in reduced economic returns and less enthusiasm from enterprises.

Third, the lack of consistent support has made it difficult for enterprises to operate. In theory, remanufacturing is an industry that is both economically and environmentally friendly. The experiences of foreign enterprises indicate that remanufacturing enterprises benefit from being large scale. In addition to the substantial investment required to update equipment in the early stage and the substantial investment in market cultivation, the insufficient government support of national policy is an important barrier. At present, the government has not promulgated tax deductions and exemptions for remanufacturing enterprises. Therefore, there is a lack of corresponding supporting policies for financial input, credit policy and so on.

Currently, the government vigorously supports the development of electric vehicles, which also has an impact on the internal combustion engine industry. The government's policy subsidies for electric vehicles, such as bus passenger transport, have led to investments in electric vehicles, and the gradual reduction in internal combustion engine vehicles means that fewer products are undergoing the remanufacturing process, thus shrinking the markets.

5.1.4 Consumption is backward, and products and technologies are hindered. First, most previous studies of remanufacturing have focused on employee-level barriers, but have noted that there is a need to increase knowledge and competencies in value chains (Besch, 2005; Kissling *et al.*, 2013; Kuo *et al.*, 2010; Mont *et al.*, 2006; Pearce, 2009a, b; Prendeville and Bocken, 2015; Seitz, 2007). However, consumers' consumption has a strong impact on market expansion. Compared with European and American consumers, Chinese consumers are less familiar with the concept of remanufacturing. There is still a long way to go before Chinese consumers recognize the quality of remanufactured products and participate in the remanufacturing process. Information about remanufactured products' sustainability should be transparently presented to consumers, to inform their purchasing decisions (Shao *et al.*, 2017; Shao and Ünal, 2019).

Second, the quality of the used parts recovered is poor. Previous studies have indicated that there are concerns about the quality control and consistency in the flow of returned goods (Bocken *et al.*, 2015; Kissling *et al.*, 2013; Ravi and Shankar, 2005; Singh and Ordoñez, 2016). Some of the used pieces recovered from socially fragmented groups of customers are on the verge of retirement, and have lost a large amount of their value. Domestic customers that have purchased foreign machines, primarily perform maintenance and routine operations in strict accordance with the instructions for use; the local machines have almost no maintenance, and they are also used illegally, such as being overloaded. This makes the foreign remanufacturing progress very smooth, with low remanufacturing costs. In contrast, when domestic products are returned to the factory, only a few parts can be used, which increases the remanufacturing cost and the final price is high, and reduces the profits. Thus, companies and customers are reluctant to participate in remanufacturing.

Third, there are barriers to developing appropriate products and technologies. A large number of exclusive product design requirements appear when enterprises move toward a CBM (Adams *et al.*, 2017; Krystofik *et al.*, 2015; Riisgaard *et al.*, 2016; Sundin *et al.*, 2009). At the same time, the many domestic manufacturers offer fierce competition, which drives the cost of parts and components very low, resulting in low value-added products, making it difficult to achieve lower cost repairs. For example, a motor may sell for more than a dozen yuan domestically and its low value-added status means it cannot be profitably remanufactured. With the implementation of the National V emission standard and the formulation of the National VI emission standard, the country is beginning to create high value-added products, which is good news for the remanufacturing industry.

At present, remanufacturing enterprises only serve their parent companies, which is inconsistent with the original idea of a remanufacturing industry. This structure does not contribute to the innovation and development of the remanufacturing industry. Of course, this structure occurs because each company's products have distinct product standards and technical patents, which makes it difficult for a remanufacturing enterprise to serve many enterprises.

5.1.5 Opportunities. This exploratory study also allows to provide with the directions on the opportunities for enterprises to develop the two dimensions of a CBM: value network and customer value proposition and interface.

Enterprises could develop their value networks in the following three ways. First, the enterprises could design a BM and strategy with higher levels of circularity. For instance, they could develop higher quality products with higher levels of EE-driven techniques and practices or more environmental friendly material-driven practices. Second, some companies do not fully realize the complexity of remanufacturing objects and processes. Higher DfX requirements must be integrated into successful BMs. For example, they must ensure an effective "disassembly for reuse" process. Furthermore, product and production standards are required for the remanufacturing industry. Third, mechanisms for entering and evaluating the market are necessary to standardize the market.

Enterprises could develop their customer value proposition and interface in the following three ways. First, adopt higher levels of customer involvement in circularity initiatives. Consumers need to be educated on consumption modes, especially the "used-for-remanufacturing" mode. It is necessary to encourage customers to actively participate in the reclamation processes of remanufacturing. Second, provide higher value-added products by integrating the internet+inventory management system to attract more users. Third, communicate the value of circularity to customers through all communication channels. This will further strengthen "bottom-up" efforts to promote remanufacturing, encourage civil society to participate in discussions about environmental issues and promote openness and transparency in the sharing of environmental information. It is necessary to teach customers to recognize the quality of remanufactured products, particularly the decreased environmental and social impact of remanufactured products. Customers can also be reached through an "internet+remanufacturing" action plan, new media platforms and other integrated information management systems.

Furthermore, policy makers should focus on regulations and incentives that build an efficient governance system that can overcome the identified barriers and facilitate enterprises' CBMs by improving their value network and customer interfaces. First, these policies should outline standards for remanufacturing design and parts disassembly, and for reclaiming used components. Second, tax deductions and exemptions for remanufacturing enterprises, harmonizing the tax rates with the manufacturing industry and corresponding supporting policies for financial input, credit policy, etc., are required, Finally, policy makers should provide support in the form of relevant policies, laws and regulations.

Table VII summarizes the main results obtained in this exploratory study in terms of propositions, opportunities and barriers. Because of its nature, the remanufacturing industry provides a suitable case to analysis the transformation and design of BMs with higher circularity.

Our main contributions can be discussed according to the research stream. First, we have shed some light into the field of sustainability in manufacturing firms by empirically testing the theoretical model suggested by Garbie (2017) on STs as well as PMs. It is interesting to notice that we found no evidence in any of our two cases about the lack of accountability (organization performance). Traditional performance measurements of accountability include product cost, manufacturing lead time, productivity, human resource appraisal, resources status and product quality. And lack of accountability drives two other STs: ST9 – human rights and customers and ST10 – businesses issues (Garbie, 2017). It reflects that in order to achieve the social sustainability, the accountability of organization performance should be emphasized.

Second, we contextualize the dynamics toward the circularity of BMs in a particular region such as China, which is due to the characteristics of their manufacturing-based

Circular business model propositions in remanufacturing industry	
Companies' understanding of opportunities and barriers have a critical stance toward a viable circular business model transformation	
High levels of integration to business eco-system is fundamental of circular business models in remanufacturing industry as the degree of interdependence is relatively higher than conventional business models	
Remanufacturing industry constitutes a fruitful scenario for circular business model innovation (design and transformation) as the "raison d'etre" for both the CE and remanufacturing paradigms are mostly serving a common goal	
Opportunities	Barriers
A company's strategy should be focused on designing business models with higher circularity	Disconnection of local governments and enterprises
Develop higher requirements for DfX practices	Lack of market access permission mechanisms
Standardize the market through access permission and evaluation mechanisms	Imperfect manufacturing standards
Adopt higher customer involvement into circularity initiatives	Imperfection and frequent changes in national and tax policies
Provide higher value-added products	Insufficient government support
Communicate the circularity through all channels with customers	Local consumer perception of the quality of remanufactured products
Use the regulations and incentives to build efficient government systems to overcome barriers	Low quality of recovered used parts
	Fierce competition
	Focus on serving only parent companies

Table VII.
Summary of results

economy and has an enormous potential for learning in the context of developing countries, a big market for circularity practices as remanufacturing, and the transformation of incumbent companies.

Third, we have built on the literature on CBM (design and transformation) to consolidate the frameworks proposed by Urbinati *et al.* (2017) and Ünal *et al.* (2018) by comparing the dimension of value network vs customer value proposition and interface. The evidence from our exploratory cases suggested that the transformation toward higher circularity of existing BMs in parental companies is primarily done by the creation of new remanufacturing company with a strong focus on the value network. However, evidence suggested that the design of the customer value proposition and interface remains underdeveloped.

6. Conclusion

This study discusses CBMs in China's automobile parts remanufacturing industry. It identifies explicit references or guidelines and explains how some remanufacturing firms have adopted a new paradigm and improved their BM. The study reveals the experiences, outcomes and lessons learned from Chinese remanufacturing organizations that have implemented remanufacturing BMs with circular characteristics. These BMs consist of the following stages: reclaiming raw materials, managing used components, developing production technologies and processes, and marketing. Several obstacles to the remanufacturing of automobile components are summarized, including policy barriers and insufficient government support, a lack of consumer awareness, and product quality and technology issues. The directions and opportunities that enterprises could develop their value networks and customer value proposition and interface were provided.

6.1 Implications for academics, scholars and policy makers

In terms of theoretical contributions, this study maps a set of ST measures for remanufacturing BMs, which consider the roles of both value networks and customer value proposition and interface. Second, for strategy managers, our findings suggest that they need to address the different levels of circularity in the value network and customer value proposition and interface by applying the 15 STs. This study provides directions for the growing number of enterprises embracing environmental sustainability as part of their strategy and that have started or are planning to apply CBM. Third, it refines and consolidates a previous conceptual framework that integrates the managerial practices of a value network dimension, with internal and external contextual factors identified through BM design and innovation research.

In terms of implications for practitioners, we suggest not to overlook the customer value and interface dimension when designing or transforming into a CBM. Both the value network and the customer value and interface dimension should be well developed for the correct delivery of the value proposition. This study also provides a guideline for managers about the different STs and managerial practices to implement higher circularity in their BMs, especially when it comes to the remanufacturing industry.

For policy makers, this study suggests that public policy should consider the overall development of the remanufacturing sector, ensuring connections and harmony between the development plans of local governments and enterprises. For instance, consistent policies are needed, especially tax or subsidy policies and policies for reclaiming used components and related processes and mechanisms. Furthermore, mechanisms for entering and evaluating markets and remanufacturing standards are needed to standardize the market.

To improve the system design and production processes of the remanufacturing sector, it is necessary to monitor the quality and related technology issues of products, which involves enhancing the knowledge or competencies in the value chain, and transparently providing information about the sustainability of remanufactured products to consumers, so that they can make informed purchasing decisions.

6.2 Limitations and further research agenda

Despite the interesting findings provided by this research, there are some limitations to be addressed. First, from an industry perspective, due to the nature of the automotive sector, studies in other circularity practices could be extended to other sectors with high potential for circularity (i.e. personal care, textiles, furniture, lighting) providing the opportunity of cross-case analysis. we examined only remanufactured products, but it can be extended to other products included in the CE classification. Second, we provided first hand-data from Chinese enterprises, but it could be interesting to compare results with other highly manufactured economies in the world to identify similarities and differences. Third, we contribute to the BM literature by comparing the value network and customer value proposition and interface; nonetheless, other BM dimension need to be added in future studies such as value capture and value appropriation. Furthermore, more cases should be added to gather stronger evidence to understand the CBM phenomena. And there is a need for quantitative and collaborative research to further extend and generalize theories and constructs that have been mainly developed from qualitative research.

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Appendix 1

Background-technology and products	1. How to remanufacture, identify and remanufacture used components and recover what kind of devices 2. What process is used to process the remanufactured product 3. Technology, technology introduction and innovation, and technical comparisons with the international (such as the USA)
Value network	1. How to establish a sales network 2. The requirements of the supplier (recycler) for the used components, how the company handles the used components, and what kind of customer objects the company faces 3. What kind of partnerships and business positioning are formed in the supply chain
Customer value proposition and interface	1. Market sales and brand promotion of current remanufactured products 2. The reputation of remanufactured products and the degree of social (national standards, customers) recognition 3. The contribution that remanufactured products make to society has an internal impact on the industry
Future prospects	1. How will the company develop and plan for the remanufacturing of auto parts in the future?

Table AI. Semi-structured interview questions of case study

Appendix 2

Stage	The first stage (2004–2008)	The second stage (2009–2014)	The third stage (from 2015 to now)
Progress	The preliminary remanufacturing	The construction and development stage	The rapid development stage
Evolution process	1. Introducing the concept of remanufacturing in China 2. Investigate automobile parts remanufacturing industry 3. Engine remanufacturing project started 4. List of the first national pilot enterprises for remanufacturing automotive parts	1. Establishment of joint ventures in cooperation with foreign-funded enterprises 2. Successfully built the initial technology, production and sales operation system 3. With the completion of the new plant, we began to expand and improve the remanufacturing capacity in a planned way 4. Loss of performance and withdrawal of capital from foreign-funded enterprises	1. Reclaiming high-quality used components and cooperating with large customers such as bus passenger transport 2. No longer recycle the used engines of scattered customers in society 3. The company began to make profits and its development was on the right track

Table AII. Evolution of Company A's business model

Corresponding author
Jing Shao can be contacted at: shao.jing@nwpu.edu.cn