

Strategic and operational remanufacturing mental
models:

A study on Chinese automotive consumers buying
choice

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3 **Strategic and operational remanufacturing mental models: A study on Chinese automotive**
4 **consumers buying choice**
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11 **STRUCTURED ABSTRACT**
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13 **Purpose:** Remanufacturing is the only end-of-life (EOL) treatment process that results in as-new
14 functional and aesthetic quality and warranty. However, applying mental model theory, we argue
15 that the conception of remanufacturing as an EOL process activates an operational mental model
16 (OMM) that connects to resource reuse, environmental concern and cost savings and is thus
17 opposed to a strategic mental model (SMM) that associates remanufacturing with quality
18 improvements and potential price increases.
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21 **Design/methodology/approach:** We support our argument by empirically assessing consumers'
22 multi-attribute decision process for cars with remanufactured or new engines among 202 car
23 buyers in China. We conduct a conjoint analysis and use the results as input to simulate market
24 shares for various markets on which these cars compete.
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28 **Findings:** The results suggest that consumers on average attribute reduced utility to
29 remanufactured engines, thus in line with the OMM. However, we identify a segment accounting
30 for about 30 % of the market with preference for remanufactured engines. The fact that this
31 segment has reduced environmental concern supports the SMM idea that remanufactured products
32 can be bought for their quality.
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36 **Research limitations/implications:** A single-country (China) single-brand (Volkswagen) study
37 is used to support the conceptualised mental models. While this strengthens the internal validity
38 of the results, future research could improve the external validity by using more representative
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3 sampling in a wider array of empirical contexts. Moreover, future work could test our theory more
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5 explicitly.
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8 **Practical implications:** By selling cars with remanufactured engines to customers with a strategic
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10 mental model that values the at least equal performance of remanufactured products, firms can
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12 enhance their profit from remanufactured products. In addition, promoting SMM enables
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14 sustainable business models for the sharing economy.
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17 **Originality/value:** As a community, we need to more effectively reflect on shaping mental models
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19 that disconnect remanufacturing from analogies that convey inferior quality and performance
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21 associations. Firms can overcome reduced utility perceptions not only by providing discounts, i.e.
22
23 sharing the economic benefits of remanufacturing, but even more by increasing the warranty, thus
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25 sharing remanufacturing's performance benefit and reducing consumers' risk, a mechanism widely
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27 acknowledged in product diffusion but neglected in remanufacturing so far.
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1. INTRODUCTION

End-of-life (EOL) treatment of products has been associated ecological and economic benefits (Seitz, 2007; Wang et al., 2014). A wide array of EOL treatment processes (EOLP) is applied in practice and has been extensively researched. Such processes include recycling, repair, reconditioning, and remanufacturing, and can be distinguished according to the depth of product deconstruction and the quality of the process outputs (Paterson et al. 2017). These processes have gained in relevance in recent attempts to design products for effective EOL treatment in reverse logistics and to define industrial material flows as a circular economy (Subramanian et al., 2014; Kadambala et al., 2017) in which EOL products and components are kept in the lifecycle. Research has explored challenges such as scheduling production when availability of EOL products is uncertain or the impact of EOL on OEMs' business strategies with a particular emphasis on EOL products cannibalising new product sales.

While most EOLP result in reduced quality as compared to the new product, remanufacturing is distinct as it (a) returns EOL products functionally and aesthetically to as-new condition, (b) applies a rigorous process of disassembly, cleaning, testing, and in some cases, technical upgrading that (c) ensures full restoration of functionality and appearance under maximum maintenance of the value created during the initial production process (Guide and van Wassenhove, 2001; European Action Plan, 2015; Paterson et al., 2017; Abbey, 2017; BSI, 2002).

However, we argue that this distinction between remanufacturing and other forms of EOLP is not sufficiently captured in the current theoretical debates and in market realities. In spite of equal or even better quality of remanufactured products, practitioners and researchers believe they must

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3 have a lower price than new and original products (Ovchinnikov, 2011; Subramanian and
4 Subramanyam, 2012; Abbey et al., 2015a). In exploring this phenomenon, we apply mental model
5 theory (Johnson-Laird, 1983). Mental models are thinking frames that determine the categories
6 that we connect with a certain concept. Mental models determine how we see and organise
7 empirical facts and how we interpret reality (Fiske and Taylor 1984). We suggest that
8 remanufacturing is mentally modelled through analogies with other EOLP. Consequently, we
9 identify an operational mental model that assumes that lower production costs result in lower
10 market prices for remanufactured products. We contrast this with a strategic mental model that
11 takes a value-based approach and posits that remanufactured products should be priced equivalent
12 to their quality and value, i.e. equal to or slightly above new and original products.
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28 We then undertake an empirical study among Chinese car consumers and explore consumer
29 preferences in a conjoint study that assesses consumer preferences for remanufactured versus new
30 engines together with different options of fuel consumption, warranty and price. Applying cluster
31 analysis, we identify four segments in our data, including the two mental models. Interestingly,
32 the strategic, value-oriented segment has reduced environmental awareness, suggesting that
33 consumers in this segment indeed choose cars with remanufactured engines for their functional
34 value, and not due to environmental motivations. In developing our argument and connecting it to
35 our empirical study, we make three contributions: (1) We identify a tension in the theorising and
36 practice of remanufacturing: While the operations and productions management community
37 assumes lower value and thus reduced prices compared to new and original products, this appears
38 counterintuitive to marketing and economic theory as remanufactured products offer by definition
39 equal or better functional and aesthetic performance and warranty. (2) We apply mental model
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3 theory to conceptualise two opposed mental models. First, an operational mental model (OMM)
4 that builds on an understanding of remanufacturing as EOLP, thus adopting a disposal mind-set
5 that highlights the environmental benefits to the consumers and expects lower prices based on
6 reduced production cost. Second, a strategic mental model (SMM) that emphasises the equivalence
7 of functional and aesthetic value created by remanufactured and new products and that would
8 expect same prices for products offering the same value. We use data from a multi-attribute
9 conjoint consumer study to empirically support the existence of both mental models in the market
10 for remanufactured car engines in China. (3) The SMM offers a stronger business case for
11 remanufacturing and may thus strongly support sustainable supply chain practices and a circular
12 economy. We discuss the conditions of SMM and develop policy, research and practice
13 implications.

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31 We develop our argument as follows. In section 2, we define remanufacturing more precisely and
32 distinguish it from other forms of EOLP. We also introduce mental models and their application
33 in business contexts. In the third section, we conceptualise an operational mental model that
34 reflects the dominant EOL debates and practices, and we contrast it with a strategic mental model.
35 We empirically explore these two mental models in an empirical study among Chinese car buyers
36 and identify both mental models in the sample (sections 4 and 5). Finally, we discuss conditions
37 for and implications of a strategic mental model in section 6.
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2. CONCEPTUAL BACKGROUND – REMANUFACTURING AND MENTAL MODELS

2.1 Remanufacturing Defined

Remanufacturing describes the return of “a used product to at least its original performance with a warranty that is equivalent or better than that of the newly manufactured product” (BSI 2009: 3.34). This definition by the British Standards Institution (BSI) defines requirements with regard to performance and warranty of a remanufactured product (Paterson et al., 2017). Through remanufacturing, a product at the end of its use or life is processed in order to restore its original functionality; the remanufactured product can thus be treated as an as-new product (Chakraborty et al., 2019). The standard further specifies that “both functional and cosmetic components shall be as-new” (BSI 2009: 3.1). It is further important that the BSI definition is congruent with those of other national or supra-national institutions such as the United States government (Federal Act, 2015) and the European Union (European Action Plan, 2015). It also corresponds with the definitions given in a broad range of academic literature (Hatcher et al., 2014; Ijomah, 2002; Paterson et al., 2016).

With respect to the quality, remanufacturing needs to be distinguished from other EOL processes. It “... is the only end of life process where used products are brought at least to Original Equipment Manufacturer (OEM) performance specification from the customer’s perspective and at the same time, are given warranties that are equal to those of equivalent new products” (Ijomah, 2002 cited in Paterson et al., 2017). The second element is warranties that are equal to or better than for the new product. These are crucial to create users’ confidence that the quality is equivalent or better compared to the new product (Wang et al., 2013). Important types of safeguards are testing systems (Ylä-Mella et al., 2015) and warranties (e.g., Hickey and Fitzpatrick, 2008). It is further worth

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3 recognising that the BS 8887-2-2009 standard defines as-new “from the user’s perspective”.
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5 Taking this definition literally would mean that products can only be considered remanufactured
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7 when users consider them to be equal to the corresponding new product.
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11 The basis of the distinct as-new quality of the remanufactured product is a well-defined process in
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13 which the product is completely disassembled, cleaned and worn-out parts are either replaced or
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15 machined in order to restore the original functional and aesthetic quality of the product
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17 (Kapetanopoulou and Tagaras, 2011). The British standard (BSI, 2010) requires the following ten
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19 steps as part of the remanufacturing process: Collection of technical documents; collection of core,
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21 i.e. the used product or component that undergoes remanufacturing; initial inspection; disassembly;
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23 detailed inspection of components; functional and cosmetic remediation of components;
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25 replacement; reassembly; testing to validate the remanufacturing process and the remanufactured
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27 process; and finally issuing of a warranty. It is this comprehensive processing that distinguishes
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29 remanufacturing from other EOL processes.
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36 Two dynamic aspects are relevant in the context of remanufacturing: innovation and upgrading.
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38 First, BSI specifies that the quality specification “applies to like-for-like products” (BSI, 2009:
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40 3.34, Note 3). This implies that the quality of a remanufactured product must match the quality of
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42 the same new and original product. Assume that a core that is remanufactured today was initially
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44 sold five years ago; the remanufactured engine thus meets or exceeds the quality standard of the
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46 original engine as sold at that time. A relevant question is how remanufacturing performs in
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48 relation to technological innovation (Zhang et al., 2019) Technological innovations such as a new
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50 compact exhaust-gas aftertreatment system (e.g. Daimler, 2019) that was introduced very recently
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52 would thus typically not be included in the remanufactured engine. The comparison of a
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3 remanufactured with a new and original product may thus only be realistic for models that have
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5 been on the market for some time.
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10 The second dynamic aspect considers upgrading of the remanufactured cores. Upgradability is a
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12 process that improves product functionality during the use phase and thereby extends the useful
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14 life span of the product (West and Wuest, 2017). Upgrading is an option that allows introducing
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16 technological innovation to remanufactured products (Chierici and Copani, 2016). Through
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18 upgrading, a remanufactured core could be of higher quality than its new and original version
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20 (Khan et al., 2018). The challenge from a reverse logistics point of view is to design the
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22 upgradability into the product (Aziz et al., 2016). For the flow of our argument, we follow the BSI
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24 assumption “that remanufacture applies to like-for-like products”. Quality dynamics through
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26 innovation and upgrading will be revisited in the discussion.
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31 32 33 **2.2 Mental Models**

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35 Mental model are cognitive representations, i.e. personal theories of how things work (Senge,
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37 1990). They include core assumptions about the elements and relationships that are relevant to a
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39 certain problem and thus allow individuals to make sense out of their perceptions of the world.
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41 Humans use categories and relationships of existing mental models to make sense of new
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43 information, and such information is used to update existing models (Johnson-Laird, 1983). Mental
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45 models are the foundation of individual and collective human reasoning, decision-making and
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47 behaviours. Humans interpret new information against the background of their mental models and
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49 tend to integrate new information into existing models (Fiske and Taylor, 1984). Mental models
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51 operate subconsciously (Wicks, 1992) and are formed through analogical thinking (Collins and
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3 Gentner, 1987). In this paper we argue that one possible understanding of remanufacturing is
4 shaped by forming analogies with other EOLP such as reuse, recycle and reconditioning.
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10 Collins and Gentner (1987) show that humans refer to a familiar domain in order to explain an
11 unfamiliar one by copying the logical structures of the familiar one. For our argument, conceptions
12 were historically shaped for the EOLP of reuse (second-hand) and recycling (aiming to capture
13 some raw materials from old products). When EOLP became more elaborate and concepts of
14 reverse logistics and circular economy were then developed, consumers and professional and
15 academic communities began to build their understanding of newer EOLP concepts including
16 remanufacturing on the existing models of reuse and recycle. Collins and Gentner (1987: 243)
17 describe how people “create new mental models that they can then run to generate predictions
18 about what should happen in various situations in the real world”. For example, one can form an
19 analogy between remanufacturing and other EOLP and predict that remanufactured products are
20 priced lower than new and original products.
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38 **2.3 Collective mental models**

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40 While mental models are at first models of individual constructions of the world, they are also
41 shared socially for intersubjective sense-making that enables communication with others (Denzau
42 and North, 1994). Collective mental models are crucial for functioning human interaction (Moore
43 and Golledge, 1976) and affect the way problems are structured and choices are made and
44 implemented (Co and Barro, 2009; Hodgkinson, 1997). They are distinct from individual mental
45 models as collective cognition includes mental conceptions about relationships and interactions
46 within the community (Weick and Roberts, 1993: 360). The mental models that a community
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3 shares are highly normative in the sense that they not only facilitate the interpretation and
4 understanding of reality, but they also impact the construction of economic and social realities
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6 (Lakoff and Johnson, 2008; Lakoff, 2010). Examples of collective mental models include the
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8 interpretation of currency deflation and inflation, with US fiscal policy focusing on avoiding
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10 deflation based on experience of the great deflation in the late 19th century as compared to
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12 avoidance of inflation in Germany based on experiences during the first half of the 20th century.
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14 In academic contexts, collective mental models shape the requirements of ‘valid’ research with
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16 psychological disciplines focusing on internal validity in highly controlled experimental settings,
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18 while communities with stronger connections to industry associations, e.g. in a supply chain
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20 management, may generally put more emphasis on external validity and the representativeness of
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22 the results for the wider market (e.g. Moosmayer et al., 2012).
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31 Collective mental models also include assumptions about markets, competitive structures and
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33 common mechanisms between demand and supply, and thus influence strategic choices and
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35 behaviours of all stakeholders (Lant and Phelps, 1999). Mental models have been introduced to
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37 analyse team effectiveness (Cannon-Bowers and Salas, 1990) and have been broadly applied to
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39 the management of teams (see Mohammed et al., 2010 for a review). Rust et al. (2016) explore
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41 how mental models shape the effectiveness of quality management and show that units with a
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43 revenue mental model focusing on customer satisfaction and retention perform better than units
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45 with a cost mental model focused on cost reductions. Co and Barro (2009) discuss how mental
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47 models of stakeholder collaboration influence the choice and effectiveness of collaborative and
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49 competitive stakeholder strategies. Moosmayer et al. (2019) analyse the reluctance of the
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51 (academic) business system to move towards more sustainable and responsible practices. They
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3 argue that utility-maximising theories taught in early undergraduate business classes shape
4 students' mental models and thus limit their ability to integrate conceptions of sustainability and
5 responsibility in later stages of their study.
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12 Similarly, we argue that the collective nature of the dominant remanufacturing mental model as
13 one of cheap prices for processed waste makes marketers price remanufactured products below
14 new ones, makes customers expect lower prices, and makes academics question arguments that
15 claim otherwise. Connecting to waste reduction, resource reuse and cost savings, this mental model
16 limits the extent to which remanufacturing is associated with quality improvements and potential
17 price increases. We develop the former as operational mental model and the latter as strategic
18 mental model of remanufacturing.
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30 31 **3. REMANUFACTURING MENTAL MODELS**

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33 Economic theory suggests that out of two products A and B, which have the same functional and
34 aesthetic performance and with B having “a warranty that is equivalent or better” (BSI 2009: 3.34)
35 than that of product A, consumers should be indifferent when the warranty is equivalent or even
36 have a preference and increased willingness to pay for B when B's warranty is better. However,
37 operations and product management theory and practice take for granted that the opposite is the
38 case for remanufactured products, which are assumed to have lower prices in spite of equivalent
39 performance (Zhao and Zhu, 2015; Zhu et al., 2016; Gaur et al., 2015; Cui et al., 2017). We suggest
40 that this can be explained by an underlying operational mental model (OMM) and explore a
41 strategic mental model (SMM) as alternative. The two models are summarised in table 1 and will
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3 be developed in detail below. The prevalence of the two mental models will later be explored in
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5 our empirical study.
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8 +++ Insert Table 1 about here +++
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10 11 12 **3.1 An Operational Mental Model (OMM) of Remanufacturing** 13

14 Substantial **terminological confusion** exists. The distinction between remanufacturing, which
15 creates like-new products with the same warranty, and other EOLP is imprecise in industry
16 standards (BSU 2002 vs 2009) as well as in academic literature (Chakraborty 2019, Kumar and
17 Ramachandran 2016) and in business practice (Zhao and Zhu, 2015; Zhu et al., 2016). Due to this
18 confusion, remanufacturing is associated with other EOLP processes and thus with using waste,
19 with lower quality and with reduced reliability for the consumer. Consumers do not perceive the
20 quality of remanufactured engines as equivalent. Guidat et al. (2015) identified general sceptical
21 customer perception with regard to remanufacturing. More specifically, remanufactured products
22 are perceived to be of lower quality (Hazen et al., 2012; Khou and Hazen 2017), which can easily
23 be explained through mental model theory. The underlying mental model contains EOL analogies
24 and thus shares the lower quality – lower price conception that is shared by all other EOLP. Price-
25 sensitive consumers may be likely to buy buying remanufactured products because they feel that
26 such products made from waste are cheaper than brand-new products (Cui et al., 2017: 1310).
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47 **Cost pricing** argumentation. Chakraborty (2019) states that “remanufacturing cost can be 50-60
48 percent less than the production cost of a new product ...” and concludes “Thus, makes the
49 remanufactured products cheaper”. This assumes cost-plus pricing by which a product’s price is
50 determined by the production cost (Schindler, 2011). While it is to be expected that
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3 remanufacturing cost is lower (Chakraborty et al., 2019), there is no immediate logic why the same
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5 functionality needs to be priced lower. Often, claims that remanufactured products have lower
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7 prices are presented without any conceptual support, so they appear to be axiomatic (e.g. Gaur et
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9 al., 2015). This is in line with an understanding of mental models as unconscious conceptions that
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11 guide our reasoning and construction of reality. In contrast, a strategic mental model would realise
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13 that the functional and aesthetic value created for the consumer is same for new and
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15 remanufactured products and prices should thus be the same. Similarly, Kumar and Ramachandran
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17 (2016) state without justification that remanufacturing “results in products that are cheaper but
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19 with comparable warranty”. These reduced prices can also be found in business practice. E.g. Zhu
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21 et al. (2016) cite the example of Steyr truck generators that sell at ¥ 44,000 when remanufactured
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23 as compared to ¥ 70,000 when new. The same mental model underlies work that considers
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25 different consumer segments and assumes that price-sensitive consumers buy remanufactured
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27 products (e.g. Cui et al., 2017: 1310; Abbey et al., 2015a). The perceived gap in value between
28
29 remanufactured and new products is even greater within the business-to-consumer (B2C) market
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31 opposed to business-to-business (B2B) (Atasu et al., 2008). This is largely due to B2C products
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33 having a considerable aesthetic emphasis whereas B2B products are purchased predominantly for
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35 their functional attributes (Goodall et al., 2014). Nevertheless, one should consider that the price
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37 can be too low, and customers may associate low prices for remanufactured products with inferior
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39 quality, thereby leading to a decrease in customer acceptance (van Weelden et al., 2016).
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49 **Disposal mind-set.** Remanufacturing a product “...instead of throwing it in a landfill protects the
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51 environment” (Hsu et al., 2016). This makes remanufacturing one option for what to do with
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53 products ready for disposal. By OMM, remanufacturing follows an EOL logic that focuses on
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3 retaining some value from waste that is to be disposed of. The disposal mind-set is associated with
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5 lower value as compared to new products; this logic holds true for all EOL processes – except
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7 remanufacturing which (a) focuses most on maintaining the product value that was created during
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9 earlier production rather than decomposing and disposing of it, and (b) reaches a quality level that
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11 is not lower but rather equal or higher than that of the original product (e.g. BSI 8887-2-2009:
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13 3.34). In line with the disposal mind-set is that remanufacturing is regularly conceptualized as a
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15 legal obligation to take care of EOL waste and to cover the cost of disposal (Hsu et al., 2016),
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17 rather than a process that maintains and enhances value.
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24 **Environmental value** to the customer. “Increasing the demand for a remanufactured product
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26 requires gaining consumers’ trust, increasing environmental awareness and reducing the price of
27
28 the product” (Cui et al., 2017: 1309). This quote well summarises the OMM: The core value that
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30 remanufactured products create for customers within the OMM mental model is not the functional
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32 product value but the environmental value. In this model, remanufacturing caters to the
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34 environmental attitudes and preferences of consumers; these might compensate for the assumed
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36 reduced willingness to pay for the functional value. It is believed that customers buy
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38 remanufactured products for environmental reasons (i.e. their process value) rather than for
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40 enhanced functional product performance (including reliability). Moreover, remanufacturers are
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42 concerned about whether customers pay for the “green” attribute of products (Guidat et al., 2015).
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44 In line with the OMM, an emphasis on ‘green’ implies that beyond these green characteristics,
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46 remanufactured products are of lower value. The remanufactured product’s additional value is
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48 considered green and not functional.
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3 **Imposition model.** Dealing with waste is a legal obligation, and violations against legislation are
4 punished (Shou et al., 2019). EOLP is necessary to avoid fines and higher cost for waste disposal
5 that is made expensive, e.g. through taxation or emission certificates. The main motivation for
6 remanufacturing in this logic would be to avoid punishment for potential violations of legislation,
7 rather than remanufacturing because it is a strategically wise business move.
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17 **Supplier push.** In the operational OMM, remanufactured products are not wanted by the consumer.
18 While consumers prefer new and original products, vendors need to push remanufactured products
19 into the market by offering at lower prices (Wong and Zeng, 2015).
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26 **Cannibalisation.** Brands and OEM lose revenue and profit because for each remanufactured
27 product sold, the market will absorb one new and original product less. Because remanufactured
28 products are sold at a lower price, this reduces revenue and profit (Chaowanapong et al., 2018;
29 Goodall et al., 2014). An additional complexity is that firms might avoid cannibalisation of their
30 own products by not engaging in remanufacturing but thereby creating business opportunities for
31 competitors (Agarwal et al., 2015).
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42 **Reverse logistics** logic. The OMM seems compatible with the idea of reverse logistics (Hsu et al.,
43 2016) in which remanufacturing is to a substantial part a logistical challenge in a linear world in
44 which the product is designed for best EOL treatment, i.e. starting from its decomposition process
45 (Lo, 2014). While Kumar and Ramachandran (2016: p.2187) point to the profit maximization
46 opportunities by “differentiating product categories or customer segments based on the differential
47 willingness to pay across different categories”, thus allowing a strategic, value-oriented view, they
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3 distinguish “price sensitive customers who prefer remanufactured products and quality sensitive
4 customers who prefer new products”, thus promoting a OMM that offers remanufactured products
5 with a discount. In the next paragraph, we thus explore the strategic mental model in more detail.
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10 11 12 13 14 15 **3.2 A Strategic Mental Model (SMM) of Remanufacturing**

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17 **Terminological distinction: precision required.** As indicated above, it is economically rational
18 to assume that a product that has the same functionality and an equal or better warranty (which is
19 how BSU 2009 defines remanufacture) should sell at a higher price. By definition, remanufactured
20 products have at least equal value as compared to like-for-like new and original products. This
21 distinguishes them from all other EOL processes. Within the SMM, this specification of equal
22 value would be taken seriously and translated into price expectations. A precise understanding that
23 is shared throughout the academic and practice communities is thus crucial for the logic of the
24 SMM to be practically viable. A remanufactured automotive product or part can be a perfect
25 substitute for a new product or any new part because of the same quality and same warranty as
26 compared to the new one (Biswas and Rosano, 2011). If this precise understanding of
27 remanufacturing as a process that is distinct from other EOLP by being at least equivalent in quality
28 and warranty was shared throughout the community, then one should expect that consumers’
29 willingness to pay should correspond and be equal to that for new products.
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49 Above, we argued that remanufacturing as EOLP carries the inferiority and low-price burden of
50 all other EOLP, which we explained through mental model theory. Similarly, the function of price
51 as quality indicator constitutes a mental model in the opposite direction. While most research
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3 explores continuous relationships, thus postulating a negative price-demand relationship for the
4 entire market, the concept of consumer segmentation suggests distinguishing different groups in
5 the market (Ovchinnikov, 2011). In particular, among price-sensitive consumers, price would be
6 negatively associated with demand; for quality-focused consumers, however, this relationship
7 could be positive because consumers associate higher prices with higher quality (Schindler, 2011).
8 In other words, because remanufacturing is offered at lower prices with a “re-...” name from the
9 EOLP range, consumers perceive quality as lower. SMM suggests that some consumers might
10 associate remanufactured engines with higher quality products, if they were sold as *field-tested*
11 *and warranty enhanced* and at 5% above new engine prices.
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26 **Value pricing argumentation.** Value pricing starts price setting from the economic value that a
27 product creates for the customer. As argued above, remanufactured products which have like-new
28 functional and aesthetic quality and an equal or enhanced warranty create at minimum the same
29 functional and aesthetic value for the customer. Value pricing theory would thus suggest that
30 remanufactured products should sell at the same or slightly higher prices than new and original
31 products (Schindler 2011; Zhao et al., 2016). In line with the SMM, Zhu et al. (2014) demonstrated
32 that quality assurance (e.g. warranties) is the important factor consumers consider in selecting
33 remanufactured products.
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47 **Sourcing mind-set.** As part of the OMM, we identified a disposal mind-set that treats
48 remanufacturing as a process to dispose of a used product at the end of a product’s life. The
49 limitation of this view is that it focuses on the disposal of old products rather than the creation of
50 new products. Within the SMM, the starting point would be the value creation for the customer of
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3 a (new or remanufactured) product; thus the question to be answered would be how to source the
4 best (most suitable) components for the best (most suitable) product for a group of customers.
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6 Considering remanufacturing with a ‘sourcing for new’ rather than a ‘disposal of old’ mind-set,
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8 would change the focus from cost-efficient disposal to value maximizing sourcing and production.
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10 This sourcing view seems viable for remanufacturing as – in contrast to the other EOLP – it can
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12 constitute the solution with the highest functional and aesthetic quality.
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19 **Functional value to the customer.** Remanufactured products are “as-new” (BS 8887-2-2009) and
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21 “provide levels of performance, reliability and lifespan that are equal to and, in many instances
22
23 exceed, those of the original engine” (ivorsearle.co.uk). This definition focuses on the functional
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25 value of remanufactured products and clarifies that performance, reliability and lifespan are equal
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27 or superior to new and original products. While allowing for additional environmental value to be
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29 created, the focus of the SMM would be on the equal or enhanced functional value of the
30
31 remanufactured product. One field in which remanufactured products are sold at the same price
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33 are products for which consumers cannot identify the EOLP characteristic of the product such as
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35 single-use cameras and various types of packaging (Akçalı and Çetinkaya, 2011).
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42 **Inducement model.** The SMM sees remanufacturing as desirable because of the value it creates.
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44 In the SMM, remanufacturing comes with the inducement of lower costs of production and, as we
45
46 argued, equal or potential increased price based on increased value creation (Shou et al., 2019 for
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48 the inducement concept). Another inducement that positively motivates firms to remanufacture
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50 may be seen in increased customer satisfaction. Firstly, increased satisfaction may result from
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52 enhanced quality experiences. Secondly, remanufacturing requires firms to closely track their
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3 products in order to manage the cores to be remanufactured in the future (Hsu et al., 2013). This
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5 improves firms' understanding of their customers and their products in use, and in this way allows
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7 them to better serve customers (Li et al., 2013). This stimulates an in-depth understanding of the
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9 customers' usage behaviours and thus enables product innovation to address common errors,
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11 process innovation to facilitate customers' use of the product along the lifecycle, and thereby
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13 allows the firm to more fully own the customer.
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19 **Customer pull.** In the strategic mental model, customers would see remanufactured products as
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21 equal or better to new and original ones and would thus develop preferences for remanufactured
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23 products. If the "equal or better" definition applies, then remanufactured products would be best
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25 of their type in the market. This connects well with work on preferences in consumer markets
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27 Cui, Wu, and Tseng, 2017).
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33 **Remanufactured products as complements in firms' sustainable product portfolio.** In the
34
35 SMM, firms might sell fewer new and original products and more remanufactured products.
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37 However, consumers with a SMM would not distinguish between the two as the quality and
38
39 warranty of the two is the same and both would thus generate the same revenues for the firm. This
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41 is already the case for products such as single-use cameras for which consumers cannot identify
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43 the EOLP characteristic (Akçali and Çetinkaya, 2011). Moreover, in an idealized, sustainable, non-
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45 growth circular economy, all elements would move in cycles without any elements being truly
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47 'new'. Note that some researchers use the term "Middle of Life (MOL)" (Östlin et al., 2009) to
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49 clarify that remanufactured cores have *not* reached the end of their lives. Even in a realistic model
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51 that combines new and remanufactured products, the negative effects of cannibalisation would not
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3 apply when OEM produce new and remanufactured products that are sold at the same price. In
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5 contrast, due to their reduced production cost, remanufactured products would result in increased
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7 profit while generating equal revenue.
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12 **Circular economy logic.** Stereotypically, SMM is more compatible with the idea of circularity
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14 (MacArthur, 2013). In contrast to ‘reverse’ logistics that comes with a linear conception of the
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16 supply chain – from supplier to customer and then back to the supplier – the idea of circular
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18 economy focuses on the circularity of product and value flows, and value would thus not be
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20 understood as something that decreases throughout the flow but is defined by the performance an
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22 element delivers in a specific step of a theoretically endless cycle.
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28 **3.3 Hypothesis**

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31 Remanufacturing is the only EOL process that creates products which are potentially more
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33 valuable than their new and original counterparts. Nevertheless, the academic and practical
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35 community seems to be caught in an operational, cost-oriented mental model. Remanufactured
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37 products are sold at discounts and are not typically included in the strategic selling plans of most
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39 firms (Ilgin and Gupta 2012). This may be due to a lack of terminological precision in
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41 distinguishing remanufacturing from other EOLP. In addition, and along with mental model theory,
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43 the perceptions of objectively reduced quality of all other EOLP spill over to remanufactured
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45 products. While literature suggests that this is in part based on consumer scepticism (Guidat et al.
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47 2015), we argue that perceptions of value, performance and prices may be shaped by producers,
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49 vendors, legislation, industry standards, and academic research. We argued that a strategic mental
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51 model exists in the market and that there are consumers with a preference for remanufactured over
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3 new engines but that the increased willingness to pay is not captured by current supply realities.
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5 The reason for expecting different segments is differences in consumer preferences (Hazen et al.,
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7 2012; Jin et al., 2016; Ovchinnikov, 2011; Zhu et al., 2014; Cui et al 2017). In our case, in addition
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9 to OMM segments that consider remanufactured engine cars only when offered with a
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11 compensation of lower price, longer warranty or lower consumption, we expect to find at least one
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13 consumer segment that follows the SMM with a preference for remanufactured engines when
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15 offered at the same conditions as a new engine. In line with the functional quality assumptions of
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17 the SMM, we expect this segment's preference for remanufactured engines not to be motivated by
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19 environmental concerns. This leads us to our fundamental hypothesis.
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26 Hypothesis: A consumer segment that applies a strategic mental model exists in the market.
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28 Specifically, this consumer segment (a) has a preference for remanufactured over
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30 new engines and (b) does not have increased environmental awareness.
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35 In order to test this hypothesis, we conduct an empirical study that aims at exploring Chinese
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37 consumers' preferences and at identifying different segments that may reflect the two mental
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39 models.
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46 47 **4. METHODOLOGY**

48 49 **4.1 Approach**

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51 We conducted an empirical consumer study at car dealerships in a Chinese tier-two city. The core
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53 of the study was a choice-based conjoint design that aimed at quantifying the utility that various
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3 product attributes generate for consumers. The relevant base product and its attribute were
4 determined in a pre-test with 112 consumers. Specifically, consumers were asked to rank 18
5 different configurations of a VW Golf 1.4T (130 HP). The configurations had either a *new* or a
6 *remanufactured* engine and varied in price (125,000¥; 150,000¥; or 175,000¥), warranty (1 year or
7 30,000 km; 3 years or 100,000 km; 5 years or 170,000 km) and fuel consumption (4.1 l/100 km;
8 5.6 l/100 km; or 7.1 l/100 km). Conjoint analysis was then applied to consumer ranking choices
9 and the resulting utility scores were used as input for a simulation of market shares of
10 remanufactured engine cars. As the simulation demonstrated relevant market potential for
11 remanufactured engines, cluster analysis was used in order to identify consumer segments that
12 may respond to different value propositions for remanufactured cars and market shares were
13 simulated for each of these segments.
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31 To understanding the empirical context of our study, it is worth noting that environmental issues
32 in the Asian and particularly Chinese car industry have recently gained in importance (Wu et al.,
33 2015; Cui, 2017). Admission restrictions for new cars have applied over the past ten years (Master
34 in Auto Industry, 2018; Beijing Transportation, 2018). However, recently, these have been slightly
35 softened (Cao, 2019). In particular, there are no restrictions imposed on the registering of electric
36 cars and newly introduced legislation and subsidy programs (Wang et al. 2014; Tian et al. 2014)
37 are better supporting remanufacturing processes (SCIO 2019, Automobile 2019), and registration
38 numbers of new cars have thus recently further increased (Cao, 2019; CPCA, 2019). Exploring the
39 extent to which remanufacturing adoption is influenced by these policies, one might find that for
40 consumers, while registering a new car comes with administrative and financial burdens, there is
41 no difference between cars with new and remanufactured engines. For manufacturers, because the
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3 restrictions determine the market size, cars with remanufactured engines cannibalize those with
4 new engines. In addition, legislation around remanufacturing, while getting easier, is still quite
5 complex (Shi et al. 2019). For instance, until recently, it was not allowed to import remanufactured
6 products and components to China (Zhu et al. 2014). In addition, firms suffer from consumers'
7 limited trust in quality claims around remanufacturing (Wang et al., 2013; PR Newswire, 2015,
8 Abdulrahman et al., 2015).
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19 Prior to the ranking task, participants were presented with “Information about remanufactured car”
20 that provided a description of the remanufacturing process and the environmental properties of
21 remanufacturing. In order to avoid any leading influence on consumer assumptions about product
22 quality and functionality relative to a comparable new engine, no concrete definition or
23 information with claims about engine performance was given. This reflects a realistic decision
24 situation in that consumers may be exposed to various marketing claims about remanufacturing
25 but may not possess accurate information regarding the quality and performance of
26 remanufactured engines.
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40 **4.2 Sample**

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42 As participants of the main study, Chinese consumers were recruited on their way to visit VW
43 (“4S”) dealerships. A total of 202 respondents (of which 3 were excluded from the cluster analysis
44 as result of the first step of the cluster analysis) performed the ranking task and filled out the
45 associated the questionnaire. A majority of respondents (70%) were men and the average age was
46 32 years (range 19 to 60 years). Respondents' educational levels reflect the connection between
47 education and economic possibilities in China with 17% reporting completion of junior or high
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3 school, 27% of professional college, 47% respondents completed a bachelor's degree and 9%
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5 postgraduate studies. Respondents were given 18 cards and requested to rank the hypothetical cars
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7 described on the cards from 1 (most preferred car) to 18 (least preferred car) by sorting the cards.
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9 The rankings were then transferred to separate survey sheets by the research assistants collecting
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11 the data.
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17 **4.3 Analysis**

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19 We applied conjoint analysis (CA) to the data resulting from the ranking task described above.
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21 This resulted in utility measures for each of the three continuous product characteristics (fuel
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23 consumption, warranty, and price) as well as for each dimension of the categorical product
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25 characteristics (new engine, and remanufactured engine) (table 2). We then used these results as
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27 input for two further analyses. First, we simulated consumer choice of a number of product couples
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29 applying Maximum Utility modelling to consumer responses (table 3). This allowed us to simulate
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31 consumers' product choices and estimate the associated market shares. We then applied the
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33 common three-step cluster analyses approach (Punj and Stewart 1983, Ketchen and Shook 1996)
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35 to the utility estimates that resulted from the CA. This enabled us to identify different consumer
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37 groups within our sample and to connect them to demographic and attitudinal variables (table 4).
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39 We then used the average utilities to describe each cluster and attribute a meaningful label.
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41 Moreover, we connected the clusters to the descriptive sample statistics and applied t tests and
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43 ANOVA to determine whether differences in the clusters discovered were significant.
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5. RESULTS

The estimated utilities from the conjoint analysis show, as expected, that higher price, shorter warranty, and higher fuel consumption are associated with negative utility (Table 2). However, consumers often are not a homogenous group and utility functions and preferences tend to vary between consumers. Indeed, pair-wise simulations of market shares based on the utility weights from the CA show that that a model with a re-manufactured engine and no compensation in the other attributes (simulation 1 in table 3) would still gain 37.9% market share. This suggests that there is a portion of the market that regards the remanufactured engine as something good in itself. The market share of remanufactured engines in *Simulation 1* reflects participants who are not just indifferent to the engine type but who actually prefer the remanufactured engine. This supports part (a) of our hypothesis that a consumer segment that applies a strategic mental model exists in the market that has preference for remanufactured over new engines. *Simulations 2* and *4* are in line with the OMM showing that consumer preferences for remanufacturing can be increased when offering lower price or reduced fuel consumption as incentives.

When segmenting the market using cluster analyses based on utility estimates, we found four clusters (Table 4). Members of the first cluster attribute substantial utility to a new engine. We thus label this segment “*New and Original*”. All other characteristics, even price, are substantially less relevant to members of this cluster. This cluster is conceptually equivalent to the dominant cluster in Abbey et al.’s (2015b) simulation study. This cluster accounts for 20 % of study participants. Respondents in the second cluster attach the most utility to fuel consumption. Their average utility of fuel consumption (-2.86) is more than twice the amount of any other cluster. We thus label this segment “*Fuel Savers*”. It comprises 29 % of observations. The utility that this

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3 cluster attributes to remanufactured engines does not deviate significantly from the average.
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5 Respondents in the third cluster attribute above-average utility to price. All other attributes are
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7 evaluated with average utility. We thus label this group, which accounts for 22 % of respondents,
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9 as "*Price Savers*". Members of the fourth cluster account for 30 % of respondents, attribute a
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11 positive utility to the remanufactured engine (1.57) and we thus label this cluster as "*Reman*". In
12
13 addition, this cluster also attributes high utility to price and average utility to warranty and fuel
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15 consumption. This is in line with the conceptualisation of our SMM mental model that sees
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17 positive value in remanufacturing.
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24 Members of the fourth cluster "*Reman*" attribute positive utility to the remanufactured engine, thus
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26 supporting part (a) of the hypothesis. In addition, we establish that this cluster reports relatively
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28 low environmental concern, thus providing support for part (b) of our hypothesis: In combining
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30 preference for the remanufactured car engine but not increased environmental concern indicated
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32 that these consumers prefer remanufactured engines but not for their environmental benefits. This
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34 supports the notion of the strategic mental model that we developed; a model that shares an
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36 understanding that remanufactured engines can be preferred for its functionality and quality. This
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38 is further supported by the observation that, while Green Consumers are typically well educated,
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40 respondents in the *Reman* cluster are significantly less educated than respondents in the other three
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42 clusters ($t = -2.54$).
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49 Both conjoint analysis and cluster analysis suggest that a consumer group with a strategic mental
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51 model of remanufacturing exists. Both analyses suggest around 30 % share. Cluster analysis as a
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53 realistic multi-attribute choice scenario suggests that there is a market segment that has a
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3 preference for the remanufactured engine without any compensation being offered and thus
4 supporting part (a) of our hypothesis on the prevalence of the SMM concept. Cluster analysis then
5 substantiated this claim by supporting part (a) of the hypothesis through an alternative method and
6 further showing that this cluster does not have strong environmental values, suggesting that the
7 created customer value is not environmental (OMM) but functional (SMM) and thus also
8 supporting part (b) of our hypothesis. We thus see supported our claim that strategic mental model
9 exists in the market that complements the operational mental model.
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21 **6. DISCUSSION**

22 **6.1 A segmented view on preferences for remanufactured engines**

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24 The results of the conjoint analyses for the entire unsegmented sample show that a remanufactured
25 engine has negative utility compared to a new engine, and price is the most important decision
26 criterion (weight 39.4). Thus, the initial results from the CA analysis suggests that consumers
27 would be unwilling to purchase a re-manufactured engine unless they are offered an incentive that
28 would compensate for the negative utility of the remanufactured engine. They also suggest that the
29 most effective incentive would be to offer a lower price, which is the attribute given most weight.
30 This is in line with the dominant OMM of remanufacturing that we identified and that is supported
31 by existing studies (Abbey et al, 2015a): Consumers overall prefer new and buy at lower prices.
32 However, the segmented view of our results supported our hypothesis about the strategic mental
33 model. This result extends the study by Abbey et al. (2015b), who identified a segment indifferent
34 to engine type: Consumers are not indifferent; we find that some consumers actually prefer
35 remanufactured over new engines. This supports research emphasising differences in consumer
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3 preferences for remanufacturing (Cui et al., 2017). When neglecting consumer differences in
4 preferences, managers will draw unsupported conclusions.
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10 Conceptually, each of the car configurations that we included in the market share simulation (table
11 3) reflects a distinct argument. The discounted product reflects the view that any remanufactured
12 product can be sold if the price discount is large enough (Abbey et al. 2015a). In contrast, the
13 remanufactured engine with reduced fuel consumption reflects the fact that remanufactured
14 products may have “better performance” (European Action Plan 2015: FN11) than the new product
15 (e.g. Paterson et al. 2017). The third option, offering a remanufactured engine “with corresponding
16 warranty” (European Action Plan 2015: FN11) also reflects the remanufacturing definition and in
17 addition addresses the information asymmetry between producer and consumer regarding the
18 actual quality of the remanufactured engine and sends a strong signal that the producer believes in
19 the as-new or better performance. Increased warranty reduces the risk for the consumer. This is
20 important because product and technology adaption research have found risk reduction to be an
21 important driver of innovation adoption (Rogers 2003, Venkatesh et al. 2012).
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40 Applying an alternative method and segmenting the market using cluster analyses, offers
41 additional insight. The “*New and Original*” is conceptually equivalent to the dominant cluster in
42 Abbey et al.’s (2015b) simulation study and reflects the OMM well. In contrast, members of the
43 “*Reman*” cluster attribute positive utility to the remanufactured engine. The fact that the segment
44 which tends towards purchasing remanufactured engines is also very price sensitive is consistent
45 with the findings of Abbey et al. (2015b). In addition, we establish that this cluster reports
46 relatively low environmental concern. This finding contradicts the OMM promoted in many
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3 studies, which postulate that consumers who are willing to purchase remanufactured products are
4 members of a green consumer segment (Abbey et al., 2015b, Giannetti et al., 2012): Consumers
5 considering the purchase of cars with a remanufactured engine are not attracted to do so by
6 environmental benefits but rather by expectations of lower prices. The remanufacturing buyers in
7 our study are thus not green consumers. This is further supported by the observation that, while
8 Green Consumers are typically well educated, respondents in the *Reman* cluster are significantly
9 less educated than respondents in the other three clusters ($t = -2.54$).
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21 **6.2 Implications of the Strategic Mental Model**

22 *6.2.1 SMM Shifts the Effects of Cannibalisation*

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24 Many OEMs fear cannibalisation, i.e. losing a portion of their new product sales to remanufactured
25 engines (Chaowanapong et al., 2018; Goodall et al., 2014). By remanufacturing their own
26 products, OEMs might create barriers to entry and avoid reputational risk from no-name firms
27 remanufacturing their cores (Agarwal et al., 2015). However, the like-new quality of the
28 remanufactured engine would promote internal cannibalisation (Atasu et al., 2010; Chakraborty,
29 2019). An additional challenge for OEM is that remanufacturing is a complex process that is more
30 interrelated with outside stakeholders (as specified in the 10-step BSI process), and implementing
31 remanufacturing strategies thus significantly complicates manufacturing and logistics processes
32 and conflict with production of new and original engines (Kapetanopoulou and Tagaras, 2011).
33 Our results suggest that remanufactured engines could be offered in a consumer market and cover
34 about one third of market share. Due to the comparable quality of new and remanufactured cores,
35 sales of remanufactured engines would reduce those of new engines. This is even more the case in
36 a context like China where growth in sales quantity is highly regulated.
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6 However, within the SMM, sales of remanufactured and new engines would be at the same price
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8 and cannibalisation would thus affect sales quantity but not the total revenue. Due to the lower
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10 cost of remanufactured cores, profitability would increase. The challenge for OEM would thus
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12 shift. It is important to develop a circular economy strategy and take ownership of the
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14 remanufacturing processes in order to protect the own brand and to tap into an attractive growing
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16 segment. OEM might even lobby for lawmakers to require branding of the remanufacturing
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18 process to ensure transparency to consumers and thus to allow them to actively choose
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20 remanufactured engines that have been processed by OEMs rather than any third party.
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26 *6.2.2 SMM Emphasises the Strategic Benefits of Remanufacturing*

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28 More strategically, our findings support Kumar and Ramachandran's (2016) idea that
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30 remanufacturing is compatible with disruptive, shared, and circular economy business models
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32 (also Kadambala et al., 2017), e.g. a service dominant logic (Vargo and Lusch, 2004). In the
33
34 circular system, the distinction between new as compared to remanufactured will lose in relevance,
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36 and value generation from use will become more important than ownership or the question of
37
38 whether components are new or remanufactured. In such a servitisation system, business success
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40 relies on owning and understanding the customer. Such owning and understanding would result
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42 from knowing when the user does what with the core: this allows better serving the customer and
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44 better maintaining the product. The complex processes of following the product and maintaining,
45
46 remanufacturing, and potentially upgrading it throughout the lifecycle is thus a prerequisite for
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48 future success. While in the OMM, the increased complexity is a burden of a costly value recovery
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50 process for lower value products, in the strategic mental model, tracking cores over the life cycle
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3 and recovering them becomes a strategic competence needed for achieving high value sourcing
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5 with an in-depth understanding of a firm's customers.
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10 *6.2.3 SMM Requires Institutionalisation*

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12 Our empirical study shows that a consumer segment in the market does uses a strategic mental
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14 model. Serving this consumer segment could allow firms to harvest increased willingness to pay
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16 and thus to making remanufacturing as an important element of a circular economy strategy more
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18 attractive. In order for this potential to materialise, we see a need for stronger institutional
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20 protection and support of remanufacturing as distinct EOLP.
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26 First, the British Standards Institute presented a clear definition for remanufacturing, requiring that
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28 remanufactured goods have the same aesthetic and functional quality and at minimum the same
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30 warranty (BSI, 2009). This is also reflected in academic literature (e.g. Paterson et al., 2017) and
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32 in business practice (Ivorsearle, 2016). However, there seems to be a lack of terminological
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34 precision and concise application of the remanufacturing term in governance, academia and
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36 industry. BSI notes in its 2002 Code of practice for remanufacture of spark and compression
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38 ignition engines (version confirmed in 2008) that “remanufactured’ is synonymous with
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40 ‘reconditioned’” (BSI 2002) but then distinguishes the two in the process of remanufacture –
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42 Specification (BSI 2010). As long as even industry bodies are imprecise, it seems natural for many
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44 consumers that they act based on an OMM that associated remanufacturing with the inferior
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46 qualities of many other EOLPs. For remanufacturing to be more successful in the market, it needs
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48 to be more easily distinguishable from other EOLP. This requires on one hand legal protection of
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50 the remanufacturing term as one that is only granted to products that meet the requirements of the
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3 strict remanufacturing definitions. This would be similar to protections of terms such as “organic”
4 or “bio” for food products in various countries. Introduction of clearly defined and well protected
5 industry and consumer labels may facilitate this process.
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12 Second, the U.S. government suggests that remanufactured engines should only be acquired when
13 they result in a cost advantage (Federal Act. 2015), which seems to favour the new, less sustainable
14 solution when new and remanufactured offer same quality at same price. In order to better support
15 the sustainable remanufacturing practice, the remanufacturing business case needs to be better
16 supported. In spite of an understandable interest of governments to save taxpayers’ money, a law
17 that disadvantages a technological solution that offers the same quality more sustainably by
18 enforcing lower prices, seems inherently unsustainable. As an implication, legislation would thus
19 need to be adjusted to account for the precise benefits that remanufacturing has to offer in contrast
20 to all other EOLP.
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35 *6.2.4 Future Research on SMM*

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37 Limitations of this study offer an avenue for future research. First, our study focuses on one brand
38 in one regional market. We chose to do so to ensure internal validity and investigate consumer
39 responsiveness to new as compared to remanufactured engine without distorting brand and country
40 influences. Compared to Western markets, car purchase in China is more influenced by social
41 context. (1) Cars are bought to create social identity and buyers make use of their social networks
42 as informational source and are strongly influenced by social norms. (2) Moreover, as compared
43 to U.S. consumers, Chinese are more focused on quality, reliability and brand. (3) Finally, they
44 pay cash rather than taking a loan and adopt new models relatively slowly (Du et al, 2014). These
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3 differences have implications for the generalizability of the results. First, the social status and
4 appearance of cars with remanufactured engines matters. Being functionally and aesthetically
5 equivalent to new engines suggests that there may be substantial market potential if the reputation
6 of remanufacturing is positive and is not communicated and perceived by consumers as just
7 another EOLP. Second, price and fuel consumption are more important in the U.S. whereas quality
8 and reliability dominate in China. The as-new quality claim may thus trigger more positive
9 associations and lead to an increased simulated market share in our Chinese sample that would not
10 be triggered in the price-centred U.S. market. Finally, car financing ensures that car buyers are
11 traceable, and Chinese consumers' attitude to full payment may thus eliminate one mechanism that
12 would otherwise facilitate the tracking processes that are crucial for remanufacturing. Exploring
13 the influence of cultural differences on consumer remanufacturing response and theorizing cultural
14 differences more explicitly is a promising avenue for future research.

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33 Despite being an effective methodology for this study, conjoint analysis places limitations on the
34 number of attributes and levels that researchers can investigate. Increasing the number of attributes
35 and/or levels requires additional cards to be used for the interview and ranking. Even with our
36 conservative use of 18 cards (and the gift incentive of a pen and ¥20), several participants
37 complained about the number of cards involved. The large number of cards presents a challenge
38 for some participants, who find it difficult to complete the ranking exercise and whose incomplete
39 results must be discarded. Future research may thus aim to add methodologically by using
40 representative real market data in order to increase the external validity of the claims.
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3 Finally, the study did not consider the financial implications of warranty-based compensation for
4 the manufacturing firms. Manufacturers would naturally want to know the impact of a longer
5 warranty on their financial well-being before deciding to implement remanufacturing. However,
6 given that we have established the presence of an over 30 % market share for remanufactured
7 engines without any form of compensation, the financial impact analysis suggested should
8 strengthen our findings.
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19 **6.3. Conclusion**

20 Starting point of our study was the identification of a tension between the economic benefits that
21 remanufacturing processes create as per their definition and the incomplete appreciation of these
22 benefits in remanufacturing research and practice. In exploring this tension, we theorized two
23 competing mental models of remanufacturing: an operational model that emphasises reduced
24 resource input, environmental benefits and lower cost, and a strategic one that emphasises the
25 performance benefits of remanufacturing as distinct EOLP that can strategically compete with new
26 products. Data from a conjoint-based study among Chinese consumers supported our strategic
27 mental model. Our findings suggest that approaching remanufacturing with a different mental
28 model allows new perspectives on some core EOLP debates in operations and production
29 management. Cannibalisation loses relevance when the two processes at stake result in the same
30 sales prices. The complexities for following cores throughout their life cycle, while still being
31 complex and costly, appear less as a threat to business when being understood as crucial
32 competence leading to customer ownership in circular economy business models. While our study
33 suggests that even today the majority of consumers may favour remanufactured over new engines
34 when some remanufacturing benefits are shared (reduced price, reduced fuel consumption, or
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longer warranty), we feel that the core benefit in remanufacturing lies in the opportunity to facilitate business models such as sharing economy solutions.

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Appendix: Tables and Figures

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Table 1: Operational and strategic mental model of remanufacturing

Characteristic	OMM – OPERATIONAL MENTAL MODEL	SMM – STRATEGIC MENTAL MODEL
<i>Fundamental logic</i>	Cost logic: remanufacturing saves material cost and is thus priced lower than new products	Value logic: remanufacturing creates the same or higher value compared to new products and thus achieve same or higher prices
<i>Terminological relation to other EOLP</i>	Terminological confusion with other EOLP.	Remanufacturing as only process to achieve as-new quality. Terminological distinction: precision required.
<i>EOLP</i>	Cost pricing argumentation	Value pricing argumentation
<i>Remanufacturing function</i>	Disposal mind-set	Sourcing mind-set
<i>Customer value</i>	Environmental value to the customer	Functional value to the customer
<i>Motivation</i>	Imposition model.	Inducement model.
<i>Market direction</i>	Supplier push	Customer pull
<i>Relation of remanufactured to new products</i>	Cannibalisation	Remanufactured products as complements in firms' sustainable product portfolio.

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TABLE 2: Estimated Utilities and Importance Weights from Conjoint Analysis

Attribute	Attribute level	Utility		Importance
		Estimate	Std. Error	Weight
Engine	New engine	0.499	0.124	21.119
	Re-manufactured engine	-0.499	0.124	
Price	¥125,000	-2.662	0.150	39.401
	¥150,000	-5.323	0.300	
	¥175,000	-7.985	0.450	
Warranty	1 year or 30,000 km	1.104	0.150	18.227
	3 years or 100,000 km	2.208	0.300	
	5 years or 170,000 km	3.312	0.450	
Fuel Consumption	4.6 l / 100 km	-1.399	0.150	21.525
	6.1 l / 100 km	-2.797	0.300	
	7.6 l / 100 km	-4.196	.450	
Constant		13.674	0.471	

TABLE 3: Market Response Simulations Based On Conjoint Analyses Results

	Preference Scores	Preference Probabilities		
		Maximum Utility	Bradley-Terry-Luce	Logit
Base model:				
New engine				
¥150,000	8.260			
3 years or 100,000 km				
6.1 l / 100 km				
Simulation 1				
<i>Base model against:</i>				
– Remanufactured engine	7.262	37.9%	47.2%	42.5%
– ¥150,000				
– 3 years or 100,000 km				
– 6.1 l / 100 km				
Simulation 2				
<i>Base model against:</i>				
– Remanufactured engine	9.923	62.9%	53.9%	62.5%
– ¥125,000				
– 3 years or 100,000 km				
– 6.1 l / 100 km				
Simulation 3				
<i>Base model against:</i>				
– Remanufactured engine	8.365	58.7%	50.4%	54.9%
– ¥150,000				
– 5 years or 170,000 km				
– 6.1 l / 100 km				
Simulation 4				
<i>Base model against:</i>				
– Remanufactured engine	8.660	65.3%	51.4%	59.9%
– ¥150,000				
– 3 years or 100,000 km				
– 4.6 l / 100 km				
Simulation 5				
<i>Base model against:</i>				
– Remanufactured engine	12.426	76.7%	59.4%	77.3%
– ¥125,000				
– 5 years or 170,000 km				
– 4.6 l / 100 km				
n = 202				

TABLE 4: Identified Consumer Clusters

Average Utility of Engine Characteristics							
mean (standard deviation)							
Cluster Number	Cluster Label	Cluster Size (%)	New Engine	Remanufactured Engine	Price	Warranty	Fuel Consumption
1	New & Original	20.1	3.30 (0.79)	-3.3 (0.79)	-0.28 (1.61)	0.92 (1.10)	-0.65 (1.02)
2	Fuel Savers	28.6	0.64 (0.80)	-0.64 (0.80)	-0.83 (1.08)	1.76 (1.67)	-2.86 (1.64)
3	Price Savers	21.6	0.66 (0.69)	-0.66 (0.69)	-4.77 (0.51)	0.98 (0.52)	-1.22 (0.71)
4	Reman	29.6	-1.57 (0.74)	1.57 (0.74)	-4.56 (0.94)	0.76 (0.73)	-0.73 (0.74)
Total		100	0.52 (1.85)	-0.52 (1.85)	-2.68 (2.3)	1.12 (1.19)	-1.43 (1.45)

Socio-Demographic Analysis of Identified Consumer Clusters

Cluster Number	Cluster Label	Cluster Size	Age	Gender (Portion of Men)	Education Level	Environmental Concern
1	New & Original	40	30.1 (8.83)	0.641 (0.486)	3.63 (1.08)	5.19 (1.22)
2	Fuel Savers	57	32.5 (7.80)	0.702 (0.462)	3.51 (1.15)	5.92 (1.17)
3	Price-Savers	43	35.0 (8.57)	0.721 (0.454)	3.60 (0.86)	5.44 (0.76)
4	Reman	59	31.5 (8.48)	0.759 (0.432)	3.17 (0.93)	5.28 (1.10)
Total		199	32.3 (8.48)	0.711 (0.455)	3.45 (1.03)	5.48 (1.11)
F value based on ANOVA			2.60 ⁺	0.531 ^{n.s.}	2.25 ⁺	4.67 ^{**}

Note: Values in brackets are standard deviations. +: p<0.1; **: p<0.01