**Understanding the market for remanufactured products:**

**What can we learn from online trading and Web search sites?**

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*Abstract*

Notwithstanding the interest it elicits from academics and practitioners, relatively little is known about the market for remanufactured products. Research, still in its infancy, has focused almost entirely on what affects willingness to pay, and our understanding of other key marketing questions, such as what drives search intensity for remanufactured products or the number of remanufactured products on offer, is limited. This paper fills this knowledge gap. Focusing on the online market for remanufactured electrical and electronic products, we empirically test whether product-specific and market-specific determinants affect search intensity and number of remanufactured products on offer, that is, number of listings. We use as inputs online search traffic, product-specific data collected from various other online sources, and relevant eBay listing data. Our analysis supports the hypotheses that search intensity for remanufactured products is associated with search intensity for, price and elapsed time since the launch of new counterpart products. Number of remanufactured products listed is associated with number of listings for new counterparts and two product-specific characteristics: presence of moving parts, and whether the product is used for personal hygiene. We discuss several implications of our findings for remanufacturers and policy makers as well as directions for future research.

**Keywords:** Sustainable manufacturing, closed-loop supply chain, green manufacturing, marketing and reverse logistics.

1. Introduction

Remanufacturing, being a multi-billion-dollar industry, commands growing interest among researchers and business practitioners increasingly aware of and interested in product take-back practices (Hagerty and Glader, 2011; Sundin and Dunbäck, 2013).[[1]](#footnote-1) Yet managers do not always find it straightforward to manage product remanufacturing (Guide et al., 1997; Atasu et al., 2008). Inadequate understanding of the market—why certain products are so popular in remanufactured condition and others are not, for instance—is a major impediment to product take-back.[[2]](#footnote-2)

Academic research in the field, albeit still in its infancy, is advancing steadily as attested by the growing number of papers. Research addressing the marketing of remanufactured products has focused almost exclusively on willingness to pay (WTP) (e.g., Hamzaoui-Essoussi and Linton, 2010; Abbey et al., 2015a; Quariguasi Frota Neto et al., 2016), according comparatively little attention to what happens prior to the point of purchase, that is, to the number of searches for remanufactured products, henceforth referred to as “search intensity,” and the nufmber of products effectively offered as remanufactured, henceforth referred to as “number of listings.” What drives WTP for remanufactured products is undeniably relevant for price setting and profit assessment, but an empirical understanding of the determinants of search intensity and number of listings for remanufactured products is equally relevant to dependent and independent remanufacturers as well as third part brokers.

The rationale for studying these factors is as follows. Although remanufacturing is in many industries still carried out on a small scale, some remanufacturers have recently developed into large organizations with turnover measured in millions of U.S. dollars (e.g., U.K.-based RDC for personal computers and U.S.-based ReCelullar for mobile phones). Among the reasons we believe the optimal size for remanufacturing operations may be increasing is the high cost of some of the equipment presently used, which makes investment worthwhile only if done on a large scale. One-person remanufacturing operations for personal computers, for instance, have been largely supplanted by complex supply chains that employ expensive tooling (e.g., equipment to magnetically wipe out data from hard drives is now essential to remanufacturers that collect computers with confidential information). Interviews with two major remanufacturers of medical equipment and a large independent computer manufacturer reveal tooling for remanufacturing medical equipment to also be costly, and hence justifiable only given sufficient volume.[[3]](#footnote-3) A sufficiently large market is also needed to recoup investment in hiring or training existing workers up to a level of expertise required by remanufacturing operations.

The increased importance of economies of scale is driving entrepreneurs and other first movers looking for new products on which to build remanufacturing businesses to assess product characteristics in terms of what might yield a market size worth tapping into. Put differently, even if WTP is high, investments in remanufacturing will pay off only if the size of the market for a product is sufficiently large. It is here that search intensity and number of listings can be helpful. Search intensity signals the size of the potential market for a remanufactured product by acting as a proxy for consumer interest. Recent research has also observed a link between search intensity and purchase intention (see, for example, et al., 2012 and Barreira et al., 2013 for car sales). Number of listings captures the size, and may also proxy for the health, of the market for a remanufactured product. For example, a considerable number of remanufactured personal computers on offer likely signals alignment between supply and demand, that is, the presence of demand and a market capable of fulfilling the demand for the product. Number of listings is also important from a consumer perspective. A higher number of listings implies access to a wider variety of products, enhancing consumers’ choice options and the utility derived from consumption.

Studying search intensity and number of listings for remanufactured products may thus yield insights into the viability of remanufacturing activity not afforded solely by analyses of WTP. Such insights are important for policy makers establishing regulations for remanufacturing as well as for online platforms, the profits of which depend on commissions per trade, and thus on market size.

Whereas most previous studies of remanufactured products rely on survey data, we use quantitative data on search intensity and number of listings retrieved from Google Trends and eBay. We supplement cross-sectional regression analyses of search intensity and number of listings on a range of potential determinants derived from the literature on remanufacturing with interviews conducted at and visits to factories of remanufacturing organizations.[[4]](#footnote-4) Key among our results are that search intensity is a function of search intensity for a remanufactured product’s new counterpart, the product’s price as new, and elapsed time since launch, number of listings a function of the number of listings for a remanufactured product’s new counterpart and two product-specific characteristics, namely, the presence of moving parts and whether the product is used for personal hygiene.

The remainder of the paper is structured as follows. In Section 2 we review papers in the literature that are closely related to our work, and explain in Section 3 why studying search intensity and number of listings adds value to this literature. In Section 4 we introduce the research questions and hypotheses, in Section 5, the methodological framework and approach to data collection. Results and managerial implications of our research are highlighted in Section 6. We conclude in Section 7, in which we suggest new avenues for research.

1. Literature review

The literature discussed in this section follows three main strands.

2.1. Modeling-based studies of the marketing of remanufactured products

Modeling-based research on the marketing of remanufactured products has focused mainly on finding optimum pricing strategies. Using game theory, Ferrer and Swaminathan (2006) derived optimum pricing strategies for both a generic OEM facing no competition, that is, a monopolistic environment, and an OEM competing with one other agent, that is, a duopolistic environment. Ferguson and Toktay (2006) also addressed both environments, accounting not only for profits accrued from remanufacturing, but also for losses due to cannibalisation. Mitra and Webster (2008) considered a similar scenario, with the difference that the manufacturer did not participate in product remanufacturing and government subsidies were available. Agrawal et al. (2015b), focusing on customized rebates, showed how a trade-in program enables a ﬁrm to improve price discrimination.

Other papers rely, explicitly or not, on the assumption of monopolistic environments. Considering a monopoly environment and pricing decisions, but multiple periods and price differentiation between new and remanufactured products, Ferrer and Swaminathan (2010) examined optimal strategies for pricing new and remanufactured versions of a generic product. Chen and Chang (2012), contributing to this stream of research an examination of pricing and lot size decisions, found a hybrid system in which a generic OEM both manufacturers and remanufacturers to outperform one in which only manufacturing is considered. Chen and Chang (2013) and Xiong et al. (2014) also studied monopolies, but departed from prior research by examining the case in which pricing strategies vary over time. Vadde et al. (2007) consider not only the pricing of the products to be remanufactured, but also the pricing (and sales) of parts, and Guide et al. (2003), Bakal and Akcali (2006), Zhou and Yu (2011), Bulmuş et al. (2014), and Mitra (2016) examine the case in which pricing and core acquisition decisions are taken jointly. Li et al. (2013) considered the joint operation of pricing and inventory for perishable products, examining specifically a multi-period ordering and clearance pricing model under a scenario of competition between new and out-of-season products. Abbey et al. (2015a) also examine pricing strategies, but complement their mathematical models with extensive empirical examination of the WTP for remanufactured products. Whereas these modelling based papers study mainly pricing and WTP, our work focuses on search intensity and number of listings, and derives its theoretical background (hypotheses) from interviews and prior academic research rather than mathematical models.

2.2. Empirical studies of the marketing of remanufactured products

Empirical research on the marketing of remanufactured products constitutes an emerging area within the closed-loop supply chain community, to which the present research on search intensity and market size is related (Souza, 2013). Closest to our work is research on the determinants of WTP and purchase intention for remanufactured products. Abbey et al.’s (2015b) analysis of drivers of consumer evaluations of remanufactured products included, in addition to brand equity and price, disgust-based reactions associated with prior product ownership. Jiménez-Parra et al. (2014), examining consumer-specific determinants of purchase intention, found consumers willing to purchase remanufactured computers to exhibit a more positive attitude towards remanufactured products in general as well as greater respect for the environment and their surroundings. Subramanian and Subramanyam (2012), investigating product- and seller-specific determinants of differences in WTP, found the discount between new and remanufactured products to be affected by the seller’s reputation. Pang et al. (2015) contributed to this stream of research by showing that, as well as product and seller characteristics, market-, seller-, and auction-specific factors also affect WTP for remanufactured products. Quariguasi Frota Neto et al. (2016) studied the factors that account for differences in WTP for second-hand, remanufactured, and new products using eBay data, and Hamzaoui-Essoussi and Linton’s (2014) examination of WTP revealed an interplay between product category, functional risk, and brand name. Hamzaoui-Essoussi and Linton (2010) and Wang and Hazen (2015) observed bargain-seeking behavior, consumers being attracted to remanufactured products by perceived value and put off by perceived risk. WTP is also affected by consumer access to information on the environmental credentials of product remanufacturers (Michaud and Llerena, 2011). Recent research suggests that consumers can be further segmented into two groups: one that is very sensitive to discounts, and another that will not buy remanufactured products at all (Abbey et al., 2015a and 2015b). The foregoing papers have in common a focus on WTP for remanufactured products.

Less closely related to our work, but nevertheless relevant, is emerging research on interaction between markets for remanufactured and new products. Guide and Li (2010) demonstrated, through field experiments, cannibalization resulting from the addition of remanufactured products to a product portfolio to differ across business-to-business and business-to-consumer product lines, and Agrawal et al. (2015a) investigated for new counterparts the impact on WTP of the availability of remanufactured products. To our knowledge, no attention has been paid to search intensity or number of listings for remanufactured products (Souza, 2013).

2.3. Using secondary data to examine product supply and demand

A significant proportion of consumers use the Internet not only for online purchasing, but also to collect information and compare offers and products (Vosen and Schmidt, 2011). Online data, specifically data on search intensity and purchase intention, can provide a great deal of information about consumer product evaluation and purchase behavior. This paper relies on two main sources of online data, namely, search traffic and number of auction listings.

Online search traffic sheds light on the habits of consumers who increasingly seek product information on the Internet. The basic component of a Web search is a query composed of one or more key terms. Online search traffic has been used in fields as diverse as medicine and marketing to detect outbreaks of influenza (Carneiro and Mylonakis, 2009; Ginsberg et al., 2009) and monitor the impact of vaccination (Desai et al., 2012). Most relevant to this study, search intensity can capture consumer interest preparatory to spend. Search engine data that reflects intensity is becoming increasingly popular among academic researchers, examples including Choi and Varian’s (2012) use of Google Trends to predict economic indicators (e.g., sales and unemployment claims in the United States), and Askitas and Zimmermann’s (2009) use of online search traffic related to job advertisements to predict trends in the German labor market. Vosen and Schmidt’s (2011) use of Google Trends to forecast private consumption demonstrated the predictive power of Google indicators to exceed that of conventional survey-based indicators. We are unaware of such data having previously been used in connection with the market for remanufactured products, the focus of the present paper.

Continuously operating marketplaces like eBay that host millions of online transactions are rich sources of empirical data for researchers (e.g., Ariely et al., 2005; Lucking-Reiley et al., 2007), in particular, those investigating remanufacturing (e.g., Guide and Li, 2010). Our use of eBay for price and number of listings data for remanufactured, second-hand, and new products is explained in Section 4.

**3. Unique contributions of this paper**

As noted earlier, recent research on the marketing of remanufactured products has investigated mainly WTP and, to a lesser extent, consumer satisfaction. We investigate instead search intensity and, also under-studied in prior research, number of listings.

In capturing consumer interest, search intensity is an ex ante measure of demand, and hence the potential size of the market, for a remanufactured product. Recognition that potential and actual market size might differ is the rationale for taking account as well of number of listings, which variable, having the disadvantage of being determined by both demand and supply factors, necessitates the complementary assessment of search intensity.

Studying the determinants of market size for remanufactured products as proxied by search intensity and number of listings is relevant to various constituencies. Insights derived from our regression results into the determinants of market size might, for example, help remanufacturing firms evaluate whether the projected scale of operations is sufficient to return an adequate investment on expensive remanufacturing equipment, policy makers legislate appropriately, avoiding, for instance, imposing minimum remanufacturing targets on products for which there may be no market, and online auction platforms like eBay predict future cash flows per remanufactured product category.

Another contribution of our work is the use of secondary data to study remanufactured products. Using eBay data on online search traffic and number of listings has the advantage over qualitative empirical methods like surveys of being based on real information seeking and purchase behavior rather than declarations about hypothetical situations. Secondary data sources also, in facilitating dynamic information retrieval across time, avoid many of the biases to which empirical methods that involve direct interaction between researcher and participants are subject (Walton et al., 2000), and respond as well to the Operations Management (OM) research community’s increasing concern over the difficulty of obtaining reliable response rates from surveys.

1. Conceptual framework and development of hypotheses

The present paper is exploratory in nature and the first to address the following research questions.

*RQ1. Which product attributes influence search intensity for remanufactured products?*

*RQ2. Which product attributes influence number of listings for remanufactured products?*

* 1. Secondary data analysis of interview transcripts

We started by examining the existing literature on the marketing for remanufactured products. This lead us to an initial set of hypotheses to be tested using real online data, as presented in Section 4.2.

These hypotheses we further developed and further evidence was considered by analysing transcripts of earlier conducted interviews. Between July 2010 and December 2015, we revisited the transcripts of 27 interviews with practitioners who worked for OEMs and independent remanufacturers, both profit and not-for-profit, engaged in remanufacturing in the fields of ICT, aerospace, health care, white goods, and consumer electronics. Interviews were conducted in person at interviewees’ place of work in the United Kingdom, Germany, France, The Netherlands, and Spain. Table 1 summarizes of the interviewees’ organizations and characteristics, sans function, anonymity having been promised. We searched the transcripts for quotes that might inform hypotheses on the determinants of search intensity and number of listings for remanufactured products.

Table 1. Summary data on interviewees



Note: Exact job titles are not provided to assure interviewee confidentiality.

4.2. Development of conceptual framework and hypotheses

Figure 1 outlines the conceptual framework that resulted from this exercise.

Figure 1. Conceptual framework.

Search intensity for new counterparts and search intensity for second-hand couterparts

Search intensity for remanufactured products

Number of listings for new counterparts and number of listings for second-hand counterparts

Number of listings for remanufactured products

Product-specific characteristics

This framework illustrates the anticipated relationship between the three sets of independent variables (on the left) and two dependent variables (on the right) examined in our study, these being whether and how search intensity is affected by (i) overall search intensity for new and second-hand counterparts, and (ii) product-specific characteristics suggested by the interview transcripts and literature search. We also examined how number of listings for remanufactured products is affected by these same variables as well as by (iii) number of listings for new and second-hand products. Note that “search intensity for new counterparts” and “search intensity for second-hand counterparts” are distinct variables, as are “number of listings for new counterparts’ and “number of listings for second-hand counterparts.”

* 1. Search intensity for new and second-hand counterparts

The literature often refers to remanufactured products as substitutes, sometimes even perfect substitutes, for new counterparts (Thierry et al., 1995; Guide and Li, 2010). Prior research also identifies a highly price sensitive segment of the consumer market that perceives new and remanufactured products as more or less interchangeable. That is, given an appropriate discount, some consumers will choose a remanufactured over a new product (Abbey et al., 2015a). Markets for new and remanufactured products being integrated, consumers may switch from a new product if a remanufactured counterpart is on offer (Guide and Li, 2010; Abbey et al., 2015a). Yet to be examined is whether search intensity for new and remanufactured products is interlinked. A product that is “hot,” that is, products with high demand, would likely also garner interest as remanufactured products, suggests a positive association between search intensity for new and remanufactured products.

Search intensity for new products may also be associated with actual purchase decisions for their remanufactured counterparts. That higher search intensity might reflect consumers’ desire for more information on, and overall interest in, a product is relevant in the case of remanufactured products because greater product knowledge is associated with higher purchase intention (Wang and Hazen, 2015). We thus expect higher levels of search intensity for a new product to indicate greater levels of interest in, and a larger number of listings for, its remanufactured counterpart.

H1a. Search intensity for new counterparts is positively associated with search intensity for remanufactured products.

H1b. Search intensity for new counterparts is positively associated with number of listings for remanufactured products.

We develop analogous predictions for the impact of search intensity for second-hand products on search intensity and number of listings for remanufactured products. Research comparing second-hand and remanufactured products being considerably less developed than that focused on the differences between new and remanufactured products, little has been articulated about whether and how consumers associate these product categories. Quariguasi Frota Neto et al. (2016) examined the link between second-hand and remanufactured products in terms of WTP, but whether search intensity and number of listings are positively associated remains an open question. Expecting second-hand and remanufactured products to tap similar markets, we hypothesize that consumers searching for information on second-hand products will likely be interested in the products’ remanufactured counterparts. We further expect consumers who search for second-hand products to be more likely to purchase remanufactured products. Search for a second-hand product for purposes of gathering knowledge on the product in a condition other than new might result in higher purchase intention. In other words, to the extent that consumers perceive second-hand to be not too dissimilar to remanufactured products, interest in information on a second-hand product should translate into higher sales for its remanufactured counterpart, which, in turn, should drive higher listing numbers.

H2a. Search intensity for second-hand counterparts is positively associated with search intensity for remanufactured products.

H2b. Search intensity for second-hand counterparts is positively associated with number of listings for remanufactured products.

4.4. Number of listings for new and second-hand counterparts

Core, being one of the main resources in product remanufacturing (Teunter and Flapper, 2011), is expected to be one of the drivers of market size for remanufactured products as captured by number of listings. Search intensity, in contrast, is not expected to be affected by core availability. Suitable sources of core include, as well as second-hand products, new products received as “false failure returns” and defective new products returned under warranty (Ferguson et al., 2006). Core availability thus being proxied by the number of new and second-hand products in the market generates the following predictions.

H3. Number of listings for new counterparts is positively associated with number of listings for remanufactured products.

H4. Number of listings for second-hand counterparts is positively associated with number of listings for remanufactured products.

4.5. Elapsed time since launch of a new counterpart

Prior research has alluded to a relationship between elapsed time since the launch of, and demand for, a product. Products with longer sales histories tend to have more predictable demand than recently launched products with little history (Fisher, 1997). This does not necessarily imply, however, higher demand, on average, for products in the former category.

We have no clear prediction of the direction of the impact on search intensity of elapsed time since launch. On one hand, if a product’s novelty engenders a quest for more information, a higher number of searches for a newer remanufactured product might result. Consumers may also be generally less interested in remanufactured products that have been long in the market. On the other hand, consumers reassured by a product’s well-established history of being offered as new might exhibit a higher ex ante purchase intention as captured by search activity.

The same ambiguity holds for the relation between elapsed time since launch and number of listings. Cores vital to the success of remanufacturing operations may not be available for recently launched products unlikely to have been returned in new or second-hand versions in sufficient quantity (Guide, 2000). The longer a product is on the market, moreover, the more time remanufacturers have to develop the take-back and recovery systems needed for successful remanufacturing. These arguments suggest a positive impact of elapsed time since launch on number of listings. Microwave ovens and other products long known to consumers, on the other hand, are likely to be functional products as defined by Fisher (1997), their long life cycles accounting for their longevity in the market (a product with a short life cycle launched many years ago, no longer being in the market, would not figure in our sample). A snapshot of products currently in the market is thus composed of long life cycle products (classified as functional by Fisher), launched recently or not, and short life cycle products (classified by Fisher as innovative), launched recently. A product with a long elapsed time since launch is thus, by construction, functional, but this characteristic is not definitive, some functional products in our sample having been launched recently.

Crediting Fisher’s (1997) suggestion that functional products’ profit margins are smaller because their relatively stable demand and long life cycles invite competition, a longer elapsed time since launch could serve as an inverse proxy for the profit margin associated with a product. Reasoning that smaller profit margins for remanufactured products should lead to smaller market size, we expect a negative impact of elapsed time since launch on number of listings, and thus obtain the following two non-directional hypotheses.

H5a. Elapsed time since launch affects search intensity for remanufactured products.

H5b. Elapsed time since launch affects the number of listings for remanufactured products.

4.6. Price of new counterparts

Prior research suggests that prices of remanufactured products are discounted relative to those of new products, which was in line with our interviews (Guide and Li, 2010; Quariguasi Frota Neto et al., 2016). As less expensive alternatives to new counterparts, remanufactured and second-hand versions of already affordable products can be expected to generate less interest among consumers. One interviewee was not very positive about the market for low-priced electronic devices. according to whom, “Some [products], like toasters or hair dryers, are already so cheap it would be hard to justify the expense of fixing and putting them back on the market.”. That was in aligned with the findings in Hagerty and Glader (2011). There being greater demand for remanufactured versions of higher cost products, and absolute profit margins tending to be, all else held constant, higher for more expensive products, we expect the price of a new product to have a positive effect on number of listings for a remanufactured product.

H6a. The average price of a new product positively affects search intensity for remanufactured products.

H6b. The average price of a new product positively affects number of listings for remanufactured products.

4.7 Weight

Given the asymmetry of information between buyers and sellers (Akerlof, 1970), consumers can only partly assess the risk of purchasing a remanufactured product. Consumer loss is possible if a product is faulty, which is more likely for remanufactured products than for their new counterparts. Previous studies have shown consumers to be cognizant of the risk of acquiring defective remanufactured products (e.g., Abbey et al., 2015b; Wang and Hazen, 2015).

We consequently expect consumers to be less interested in heavier products, such as remanufactured refrigerators or dishwashers, than in smaller, lighter, and hence easier and cheaper to return, products like smart phones. Transportation costs may also play a role, many heavy products tending to be delivered at no cost when purchased new, but incurring shipping charges when purchased as remanufactured. We thus expect a negative effect of product weight on search intensity. Weight will also affect supply. One of the organizations we visited did not sell refrigerators or washing machines via eBay; its larger, heavier products being expensive to transport, shipping costs would have rendered the entire remanufacturing operation non-profitable, and it hence sold only locally. We thus obtain the following predictions.

H7a. Weight negatively affects search intensity for remanufactured products.

H7b. Weight negatively affects number of listings for remanufactured products.

4.8. Presence of moving parts

Whereas Abbey et al. (2015b) showed consumers to be suspicious of the quality of remanufactured versions across a range of products, our interviews suggest that concerns about failure are particularly strong for products with moving parts. Questions asked by one consumer, according to a technician interviewed in one of the companies we visited included: *“Does this washing machine still work well? Do parts move inside? Is it noisy?”* Such concerns do not exist for electronic products without moving parts. A director we interviewed said that a remanufactured printer is likely to be viewed with more suspicion than a remanufactured tablet because of moving parts. This perception is so entrenched that the company, having sold only a few in the course of a year, stopped posting new auctions for remanufactured printers. We thus expect ex ante consumer demand and ex post number of listings to be lower for remanufactured products that contain moving parts.

H8a. The presence of moving parts negatively affects search intensity for remanufactured products.

H8b. The presence of moving parts negatively affects number of listings for remanufactured products.

4.9. Personal hygiene products

Abbey et al. (2015b) found that some consumers feel disgust towards remanufactured products and will not buy them whatever the discount. Prior research had already established disgust to be an element in purchases especially of second-hand products that come into contact with the buyer’s body (Rozin and Fallon, 1987; Xu et al., 2014). This is commonly termed the law of contagion (Rozin and Fallon, 1987). We thus expect lower search intensity and, although the supply of core is ample, a less developed market, for remanufactured versions of personal hygiene products. It is perhaps noteworthy that none of the organizations in our sample of interviewed companies remanufactured personal hygiene products.

H9a. Intended use for personal hygiene negatively affects search intensity for remanufactured products.

H9a. Intended use for personal hygiene negatively affects number of listings for remanufactured products.

1. Methodology

We describe here our data collection procedure for the quantitative sample, regression methodology, and operationalization of variables.

Data on number of listings were collected between December 23, 2013 and January 7, 2014, on browsing activity, for the year 2012, prior to the data on number of listings in order to examine pre-purchase information seeking.

The sample is composed of popular products found on Amazon.com.[[5]](#footnote-5) We focus of electronic and electrical goods, these constituting the most important business-to consumer (B2C) markets for remanufactured products, remanufactured mobile phones and personal computers being sold in the millions (Quariguasi Frota Neto and Van Wassenhove, 2013).

*Search intensity for remanufactured products – dependent variable (*SIR*)*

We measured consumer interest in each of the remanufactured products in the sample using search volume as a proxy for level of browsing activity. We extracted data for the year 2012 from Google Trends (source: http://www.google.com/trends/), which measures volume search for Google, the most popular search engine worldwide (source: Alexia, http://www.alexa.com/siteinfo/google.com). We operationalized this variable as follows. Using Google Trends, we calculated the percentage of the total number of searches for all remanufactured products in our sample directed at each of the sample products. An *SIR* for “*remanufactured GPS Navigator*”equal to 2% thus means that two of every 100 queries for remanufactured products contained in our sample were for the term “*GPS Navigator*.”

*Number of listings for remanufactured products – dependent variable (*NLR*)*

We measured number of listings for remanufactured products using data drawn from auction listings on eBay.com, specifically, the number of products auctioned, a product being defined as remanufactured if identified as such by the seller. Products in our sample described as “manufacturer refurbished” and “seller refurbished” are essentially products remanufactured by OEMs and independent remanufacturers.

*Search intensity for new and second-hand counterparts (*SIN *and* SIS*)*

Levels of browsing activity for new and second-hand versions of a remanufactured product (*SIN* and *SIS*, respectively) were determined in a manner similar to that used for the dependent variable (*SIR*).

*Number of listings for new and second-hand counterparts (*NLN *and* NLS*, respectively)*

Number of listings for new (*NLN*)and second-hand (*NLS*) versions of remanufactured products were determined in a manner similar to that used for the dependent variable (*NLR*).

*Elapsed time since launch of a new counterpart* (TE*)*

Elapsed time since product launch (*TE*) is defined in months, drawn and triangulated from diverse online sources (e.g., science.howstuffworks.com and inventors.about.com).

*Price of new counterpart (*P*)*

We operationalized this variable by calculating, in dollars, the median price of the product sold as new on eBay.com, limited to “*Buy it now*” (i.e., auctions were not taken into account) and “*US only*”(forlocation).

*Weight (*WG*)*

Product weight rarely being mentioned on eBay, we measured this variable for each product category by randomly selecting, from among eBay listings that include it, the weight of one item. Failing this, we searched for weight on the manufacturer’s website. This simple sampling strategy reflects our belief that products in the same category are roughly equivalent in weight, and is consistent with the information on which consumers would have to rely when researching weights of products listed on eBay.

*Presence of moving parts (*MP*)*

Two researchers independently classified products as having moving parts (*MP*), compared their results, and together resolved the two cases in which their classifications differed.

*Personal hygiene purposes (*PH*)*

The two researchers who independently classified products as being used for personal hygiene achieved 100% consensus.

We tested dependencies between the dependent and independent variables by using R software to estimate OLS regressions. We transformed the continuous (non-categorical) dependent and independent variables into logarithms, adding 0.0001 to each variable in order to avoid calculating the logarithm of zero. Log-log models are known to be flexible and easily interpretable. Working with logarithmic transformations enabled us to interpret regression coefficients as elasticities (Christensen, 2006; Verbeek, 2008).

To formally assess whether to use a logarithmic rather than linear specification for the dependent variables in our regression models, we implemented the MacKinnon-White-Davidson PE test for comparing linear-linear versus log-linear specifications in OLS regressions, as described in Verbeek (2008). Our test results suggested log to be preferable to linear transformations of the dependent variables. We then tested different specifications for each of the independent variables. As suggested by Hansen (1999) and Verbeek (2008), we used the Bayesian Information Criterion (BIC) to select the best model for models 1 and 2 below, being equations with the dependent variables search intensity for remanufactured products (SIR) and number of remanufactured products listed (NRL). We considered as potential candidates for regression models all combinations of the independent variables in linear, logarithmic, and quadratic form. The log-log stood out among the 2,187 (37) and 19,683 (3­9) of model specification candidates, for respectively models 1 and 2, considered by our search algorithm as a good fit for our sample for both models. The BIC of our log-log models was quite close to that of the optimal models identified by our search algorithm. Our log-log models having a much simpler interpretation than more complex models, with only marginal differences in BIC, we opted to report the log-log specifications in this paper. Comparing adjusted R2s of alternative regression models yielded similar results. Our log-log models have an adjusted R2 virtually similar to those of the optimal models (across thousands of possible specifications), but are more parsimonious (relative to the optimal models) that might make them more attractive to practitioners trying to estimate market size for remanufactured products. Results of these model specification tests are available upon request.

Detailed model specifications based on the relations depicted in Figure 1 are outlined below.

*Log (SIR) = β0  + β1 Log (SIN) + β2 Log (SIS) + β3 Log (TE) +β4 Log (P) + β5 Log (WG) +*

*β6 MP + β7  PH ( Model 1)*

*Log (NLR) = β0  + β1 Lo g(NLN) + β2 Log (NLS)+ β3 Log (SIN) + β4 Log (SIS) + β5 Log (TE) +β6 Log (P) + β7 log(WG) +β8 MP + β9 PH (Model 2)*

1. Empirical results and implications
   1. Results

Table 2 shows the correlation between the independent variables. Collinearity between independent variables is generally not a concern, all, save one pair of variables, *SIN* and *SIR*, being well below the 70% level. Variance Inflation Factors (*VIF*) were equally below accepted levels, and below the threshold of 10 (O’brien, 2007).

Table 2. Correlation matrix



Table 2 provides pairwise Pearson’s correlations between the explanatory variables (continuous variables being measured in logarithmic form). \*, \*\*, \*\*\* indicate statistical significance at the 10%, 5%, and 1% level.

Table 3 shows regression results for models (1) and (2). The explanatory power of the models is high, as indicated by an R2 of 0.618 for the model that predicts search intensity, and 0.808 for the model that predicts number of listings.

Results for model (1) are as follow. As predicted by hypothesis H1a, we find a significant positive impact of search intensity for new counterparts (*SIN*) on search intensity for remanufactured products (*SIR*). Further, consistent with hypotheses H5a and H6a, respectively, *SIR* is significantly influenced by elapsed time since launch and significantly positively affected by price.

The significant positive impact of number of listings for new products (*NLN*) on number of listings for remanufacturing products (*NLR*) found in model (2) is in line with hypothesis H3. Consistent with hypothesis H9b, we find a strongly negative impact on *NLR* of a categorical variable indicating use for personal hygiene. We also find weak evidence (*p*-value < 0.10) of a significant relation between the presence of moving parts and *NLR*, but in the direction opposite that anticipated by hypothesis H8b.

Table 3. Determinants of search intensity (*SIR*) and number of listings (*NLR*) for remanufactured products

This table presents the results of regression analyses that test level of search intensity and number of listings for remanufactured products. The first column refers to model 1, the second to model 2. The value outside brackets denotes the value for *β;* that between brackets, t-values. N denotes the number of observations. \*, \*\*, \*\*\* indicate statistical significance, established through two-tailed *t*-tests, at the 10%, 5%, and 1% level.

6.2. Discussion and implications of results

We discuss here deeper interpretations of our significant and nonsignificant regression results, and highlight implications for organizations engaged in product take-back and policy makers legislating for remanufacturing.

The explanatory power of the regression models appears sufficiently good to suggest their effective use by practitioners to predict market size for remanufactured products. We find as a significant result of model 1 that search intensity for remanufactured products is positively influenced by search intensity for their new counterparts. This observed positive association is consistent with the strong spillover between markets for new and remanufactured products highlighted in previous studies (Quariguasi Frota Neto et al., 2016). Our finding of a significant negative impact of elapsed time since launch on search intensity suggests that consumer excitement about, and higher asymmetric information associated with, newly launched products dominate consumer comfort with purchasing remanufactured products longer in the market. We find higher prices for new products to have the expected positive impact on consumer interest in their remanufactured versions. The associated discount may not be sufficient to entice consumers to buy remanufactured versions of relatively inexpensive products. Consumers might consider, for example, buying remanufactured personal computers that offer a high absolute discount, but not a remanufactured USB flash drive with identical percentage discount, as the latter costs only a couple of dollars.

Model 2’s finding of a positive impact for number of listings of new versions of the same product is consistent with the importance of core availability to the viability of markets for remanufactured products. We do not find strong evidence that product-specific characteristics affect number of listings, a notable exception being the strong negative link between number of listings and whether a product is used for personal hygiene.

Our findings suggest that search intensity and listings for new products, being closely connected with market size for remanufactured products, should be closely monitored by OEMs and independent remanufacturers engaged in product take-back. The quantitative data on which our study relies, having been obtained from publicly available sources, can be exploited by any organization to this end. Moreover, our results suggest that OEMs and independent remanufacturers should divert more capacity to the remanufacturing of recently launched, more expensive products and less to personal hygiene products. That the determinants of search intensity largely differ from those of number of listings could be explained as follows. Search intensity captures ex ante consumer interest, whereas the number of listings captures actual market size, which is consequent to the interaction of consumer demand with the supply of remanufactured product. We thus encourage joint consideration of these variables by OEMs and independent remanufacturers trying to gauge market size for remanufactured products.

Among factors that do not significantly influence market size for remanufactured products that nevertheless merit consideration are search intensity and number of listings for second-hand products (*SIS* and *NLS*, respectively). That these do not influence the dependent variables could be due to the fact that *SIS* and *NLS* are highly correlated with the corresponding variables for new products. As can be seen in Table 2, the correlation between *SIN* and *SIS* is 0.62, and between *NLN* and *NLS* 0.42. Our findings thus suggest that information from the second-hand market adds little value to examination of the market for new products. Nor do we find any impact of product weight in any of the models, and the moving parts categorical variable is nonsignificant in model (1) and marginally significant, with the wrong sign, in model (2). The latter findings suggest that consumers do not worry exceedingly about potential faults that might necessitate the return of remanufactured products. We believe this could be due to the increasing efforts of remanufacturing OEMs and some independent remanufacturers to address product failures appropriately and efficiently. Many remanufactured products, for instance, enjoy the same warranty protection as new products (Atasu et al., 2010). Our findings tentatively suggest that “disgust” issues dominate perceived risks of product failure as a deterrent to the development of markets for remanufactured products.

1. Limitations and avenues for further research

The present research departs from previous research in investigating search intensity and number of listings for remanufactured products. Understanding these factors is fundamental to identifying potentially untapped markets (which might be indicated by high search intensity and a low number of listings) and assessing market size, which is crucial for remanufacturing activities given the high up-front investments presently required for remanufacturing equipment and staff training. Methodologically, our research differs from earlier complementary studies focused on WTP for remanufactured products that have relied on survey data, which, albeit often useful, are subject to social desirability and other biases. Our use of quantitative data obtained from Google Trends, eBay, and other sources captures genuine rather than reported interest and actual numbers of listings.

These contributions notwithstanding, our research admits some obvious limitations that suggest interesting avenues for additional research. Our study is limited, for example, by its focus on eBay, which, although a major outlet for remanufactured and second-hand products, is but a single online platform; we readily acknowledge that electrical and electronic products are traded on other platforms as well. We further acknowledge our research, given its exclusive focus on the online market, to possibly have limited or no application to brick-and-mortar markets, and our main unit of analysis being general product types, future research might usefully investigate determinants of remanufacturing market size for specific product models. Our measurement of product weight, moreover, is by construction only an approximation, this information seldom being provided on eBay.

We propose investigating as well manufacturer-specific determinants like company size and brand value, anecdotal evidence suggesting that consumers considering remanufactured products are more interested in the premium end of the spectrum (examples being Bosch and Apple). It might also be informative to examine whether being offered in online stores as opposed to online auctions is indicative of higher quality in remanufactured and second-hand products, and whether this translates into increased interest in the product in the overall market. A much larger sample of products of different brands would be needed for such a study.

The present paper also suggests the possibility of basing forecasts of future demand and market size for remanufactured products on the independent variables. The future market for a remanufactured version of a newly launched product could, for example, be forecasted on the basis of current levels of interest in new and second-hand versions as well as certain product characteristics, such as price as new. Our results argue for close monitoring of markets for new products when devising forecasting models to assess the attractiveness of remanufactured lines.

Research that improves understanding of geographic factors that affect consumer interest in remanufactured products is also wanted. An investigation of country-specific determinants could test the effect of socioeconomic and cultural issues; are remanufactured or second-hand mobile phones, for example, more highly sought in developed or developing countries? To our knowledge, no paper has yet addressed this issue, which is important to remanufacturers expanding into new markets.

Future research might also extend these analyses to products sold business-to-business (B2B), such as hospital equipment and aerospace engines. We further propose the examination of luxury goods, which are becoming popular as remanufactured products.

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1. The term “product” is in this paper used to describe a category of products. By way of example, “Laptop” and “Electronic scale” are referred to as “products.” We do not differentiate between types of laptops or electronic scales. In other words, we are asking the question why so many personal computers are being sold, not why a particular brand or model of remanufactured computer sells, on eBay. [↑](#footnote-ref-1)
2. “Remanufactured” is here understood to denote a product that was subject to any operation by which a second-hand product is made to satisfy a quality standard equivalent to that for a new product, as in Thierry et al. (1995). Although such operations are often differentiated on the basis of the level of recovery activity (e.g., as described by refurbishing, rebuilding, and reconditioning), we use the generic term “remanufacturing” throughout this paper. [↑](#footnote-ref-2)
3. Section 4.1 provides a detailed description of our interview sample. [↑](#footnote-ref-3)
4. Interviews and factory visits complement insights obtained from the academic literature. The interviews were **not** carried out with the sole purpose of providing evidence for this paper, and should thus be considered as secondary source only. Rather, we have consulted the transcripts of interviews and visit notes we have carried out for a previous project, which was published in Stindt et al (2016). [↑](#footnote-ref-4)
5. Computers, Computer Accessories & Office, Cameras, Tablets, Phones, Video Game Consoles, Audio Accessories, Car Electronics, TV & Home Theatre, Appliances, and Personal Health & Beauty. Products include: Desktop, Laptop, Netbook, MacBook, iMac, All-in-One Computer, Keyboard, Mouse, Printer, Scanner, Monitor, Copier, Fax Machine, Video Projector, WebCam, Wireless Router, Hard Drive, External Data Storage, Calculator, Voice Recorder, Electronic Dictionary, Flash Drive, USB, Processor, Video Graphics Card, DVD Drive, TV Tuner Card, Digital Camera, Film Camera, Camcorder, Digital Photo Frame, Tablet, iPad, iPod, e-book Reader, PDA, Mobile Phone, iPhone, Phone, Smartphone, Play Station Console, Xbox, Wii Console, Mp3 Player, Mp4 Player, Headphone, Microphone, Speaker, Cassette Player, Car Audio, Car Video, Radar Detector, GPS Navigator, CB Radio, TV, Blu-ray Player, DVD Player, Recorder, Digital TV Converter, Home Theater System, Washer, Dryer, Fridge, Refrigerator, Freezer, Oven, Microwave, Dishwasher, Vacuum Cleaner, Air Conditioner, Heater, Espresso Machine, Coffee Machine, Blender, Bread Machine, Deep Fryer, Electric Toothbrush, Electric Shaver, Electronic Pulse Massager, Blood Pressure Monitor, Digital Thermometer, Ear Thermometer, Heart Rate Monitor, Pedometer, Sport Watch, Stopwatch, Alarm Clock, Treadmill, Elliptical Trainer, Exercise Bike, Vibration Trainer, Rower, Stepper Pilates Reformer, Electronic Scale, Electronic Cigarette Lighter, Electronic Tobacco Cigarette Roller, Hair Dryer, Hair Straightener, Curling Iron. [↑](#footnote-ref-5)