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Optimal pricing for new and remanufactured products

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ABSTRACT

This work investigates the optimal pricing of new and remanufactured products using a model of consumer preferences based on extensive experimentation. The experimental investigation reveals two distinct segments of consumers. One segment is relatively indifferent between new and remanufactured products and displays high sensitivity to price discounts. The second segment shows strong preferences for new products—with an accompanying aversion to remanufactured products—and realtively low sensitivity to price discounts. The pricing analysis examines several scenarios involving a new product manufacturer, ranging from a simple monopolist scenario to a more complex scenario involving competition with third-party remanufacturers. In contrast to the usual finding that new product prices should decrease when competitive remanufactured products enter the market, the introduction of market segments reveals a robust finding across all scenarios: when remanufactured products enter the market, the optimal price of the new product should increase. Through appropriate pricing of new products, the OEM can mitigate the effects of cannibalization and increase profitability.

1. Introduction and motivation

The market for remanufactured products is large and growing. Recent estimates for remanufactured product sales exceed $100 billion per year with consumer markets representing approximately $10 billion worth of sales per year (Giuntini, 2012; Hauser and Lund, 2003). Although business-to-business sales still dwarf consumer sales of remanufactured products, consumer markets for remanufactured products are growing rapidly, accelerated by the widespread popularity of Internet sales and on-line auctions. The increased demand and availability of remanufactured products in competition with new products pose vexing challenges for the OEM who manufactures new products.

Faced with competition from remanufactured products, OEMs struggle to develop a coherent remanufacturing strategy: whether to enter the market with a remanufactured product and, if so, how to price the products within a portfolio of both new and remanufactured offerings. Interviews with managers also revealed that cannibalization of new product sales by remanufactured products represents a significant concern for OEMs. For instance, at Hewlett–Packard, executives expressed their beliefs about cannibalization by stating that, "for every four unit sales of a remanufactured product, they lost one new product sale" (Rysavy, 2001). Other firms have focused on eliminating returns in order to block third-party remanufacturing and prevent cannibalization (Blackburn et al., 2004; Ferguson et al., 2006). Even when returns are unavoidable, firms such as Bosch Tools, NA have hesitated to offer a remanufactured version of some products for fear of diluting both their brand and cannibalizing their new product sales (Valenta, 2008).

Discussions with product managers at OEMs revealed that the managers often make pricing and other strategic decisions about remanufactured products in an environment of fear and uncertainty—fear of cannibalizing new product sales and uncertainty about consumer preferences and willingness to pay for remanufactured products. Given these concerns and lack of appropriate information, some product managers—those who do choose to offer a remanufactured product—follow ad hoc pricing strategies.

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In many cases, those pricing strategies amount to simply pricing the remanufactured product at some prescribed discount off the price of a comparable new product through educated guesses or historical rules of thumb.

To address these concerns, this paper develops models to help OEMs evaluate the risks of cannibalization, make strategic decisions about entering the remanufacturing market, and to provide guidance on product pricing—the joint pricing of the new and the remanufactured products. Though a sizeable literature on remanufactured consumer products exists, most models use standard, theoretical assumptions about consumer preferences for new and remanufactured products that have not been fully validated (Watson, 2008). Further, Guide and Van Wassenhove (2009) raised concerns about the validity of these theoretical consumer behavior models and called for empirical studies of consumer preferences for both new and remanufactured products. In light of these concerns, the empirics of Section 3 investigate consumer preferences and reveal distinct departures from the classical theoretical model assumptions. Those departures from the assumptions of the classical theoretical models reveal deficiencies in the existing literature that limit the existing models' effectiveness for use in practice. Based on the empirical findings, the resulting models of Section 4 are quite distinct from previous classical theoretical models. As a result, this study differentiates itself from previous research and provides constructive new insights for practitioners regarding consumer preferences for the products.

Based on these concerns and open questions, this research has twin objectives. The first objective is to gain empirical understanding regarding the nature of consumer preferences for new and remanufactured products. The second objective is to use the empirical findings of consumer behavior as a means to inform practice on remanufacturing strategy. Those strategies provide practitioners with insights for improved pricing/production decisions when remanufactured products are introduced to the market. The empirical analysis, detailed in Section 3, addresses the first objective through a tailored experiment, using a general population of U.S. consumers, to facilitate development of a new analytical model of consumer preferences for new and remanufactured products. This model differs in significant ways from the consumer behavior models that have been the de facto standard in the remanufacturing literature. In particular, through use of a highly generalizable mixed between and within-subject mixed model with subsequent regression analyses, the experimental work identifies distinct segments of the consumer population that have markedly different preferences for remanufactured products. Providing insights for practice through improved strategy— the second objective—requires use of the consumer behavior model as input into an analytical pricing model. The analysis of this empirically informed analytical model constitutes the second stage of the research. This second stage, covered in Section 4, develops market entry and pricing policy decisions under different scenarios that capture the variety of market conditions an OEM would face in competition with remanufactured products. The analytical results provide new insights into the appropriate discount levels for remanufactured products and yield counter-intuitive results for pricing new products. The results show that optimal pricing for new products often embodies price-increasing competition: competition from the remanufactured product causes the optimal price of the new product to increase, rather than decrease.

2. Related literature

In addition to the research cited in Section 1, this manuscript draws on an extensive body of literature in consumer behavior, market segmentation, and remanufacturing strategy. In doing so, this manuscript addresses two fundamental elements of remanufacturing strategy. The first fundamental element addresses optimal pricing for the two products when a new product and a remanufactured product compete in the same market. The second fundamental element studied identifies the optimal level of production if the firm decides to offer both new and remanufactured products simultaneously. Previous research addressing these questions has followed a methodology that has its roots in classical market segmentation economics. Specifically, the market segmentation studies analyze the price and positioning of a portfolio of products by first positing a theoretical model for the distribution of consumer preferences, then using that assumed model to determine the optimal prices and positions under competitive equilibrium (Hotelling, 1929; Mussa and Rosen, 1978; Moorthy, 1984; Vandenbosch and Weinberg, 1995).

Although the market segmentation literature provided the research template used in theoretical studies of remanufacturing strategy, there are important differences between the two problems. Remanufacturing decisions are structurally simpler than those of the classical market segmentation problem because, with remanufacturing, the product positioning decisions are fixed a priori. In other words, there are existing new products with defined positions and a remanufactured product—functionally equivalent to the new product that may also enter the market. In addition, the realities of a closed-loop supply chain impose constraints on the production quantities of remanufactured products. The amount of remanufacturable cores is limited to a fraction of prior production based on a firm's reverse supply chain and product acquisition management (Guide and Van Wassenhove, 2001).

The seminal paper by Majumder and Groenevelt (2001) initiated a stream of research on remanufacturing strategy. The Majumder and Groenevelt paper, and most of the subsequent papers on remanufacturing strategy, adhere to traditions of market segmentation research by beginning with an assumed *theoretical* model of consumer behavior. These theoretical models assume that all consumers would buy a remanufactured product at a sufficiently large discount on some distribution—usually a uniform distribution—of willingness-to-pay preferences across an interval of prices. With few exceptions, these models generally employ a linear relationship between the discount and the consumer's preference for remanufactured products (Atasu et al., 2008; Debo et al., 2005; Jin et al., 2007; Vorasayan and Ryan, 2006). In all of these studies, the consumer behavior model finds the competitive equilibrium to determine the price and production quantities for the new and remanufactured products. In related work, Aydinliyim and Pangburn (2012) consider a problem that is similar in structure to the remanufacturing strategy problem. In their model, consumers choose between two products that differ only in their packaging with reduced-packaging products offered at a discount. Unlike the remanufacturing strategy models, the theoretical consumer behavior model used in their work allows for the possibility that the willingness-to-pay functions may intersect. In other words, some fraction of consumers (e.g., green consumers) might be willing to pay a premium for the reduced-packing option.

In contrast to the models based on the common set of theoretical assumptions, motivation for this manuscript stemmed from the growing body of empirical evidence that the theoretical models of consumer behavior used in prior studies may be deficient and fail to capture accurately the complexity of consumer preferences. A recent field experiment using eBay auctions of both new and remanufactured products found that consumers tended to fall into one of two distinct segments (Guide and Li, 2010). One segment only bid on new products and stated in follow-up surveys that they would not consider purchasing a remanufactured version. The second segment contained deal-seeking, functional consumers who displayed relative indifference between new and