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Quality design and environmental implications of green consumerism in remanufacturing

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ABSTRACT

We study quality design and the environmental consequences of green consumerism in a remanufacturing context. Specifically, a firm has the option to design a non-remanufacturable or a remanufacturable product and to specify a corresponding quality, and the design choices affect both the production costs and consumer valuations associated with the product. On the cost side, remanufacturable products cost more to produce originally, but less to remanufacture, than non-remanufacturable products cost to produce. Analogously, on the consumer side, remanufacturable products are valued more, but remanufactured products are valued less, than non-remanufacturable products are valued. Given this, we investigate the environmental consequences of designing for remanufacturability by first defining a measure of environmental impact that ultimately is a function of what is produced and how much is produced, and then applying that measure to assess the environmental impact associated with the firm's optimal strategy relative to the environmental impact associated with the firm's otherwise optimal strategy if a non-remanufacturable product were designed and produced.

1. Introduction

"Green" has become a buzzword that penetrates daily life. Among consumers, in particular, there is a growing trend to incorporate socially responsible considerations into purchasing decisions and to buy eco-friendly products accordingly (Layton, 2008; Grekova et al., 2014; Eurobarometer, 2008, 2009). This trend is referred to as "green consumerism" and is conceptualized as 'a personal ethical orientation or as a set of pro-environmental personal values and attitudes that inform a particular form of socially conscious or socially responsible decision making' (Moisander and Pesonen, 2002, p. 329). Basically, green consumers are those who are willing to trade-off, to varying degrees, conventional economic attributes of a product, such as price and quality, for example, for environmentally friendly features. Indeed, a significant portion of consumers even are willing to pay a premium for products with these features. Based on their recent meta-analysis of approximately 80 empirical studies published or presented between 1996 and 2012, for example, Tully and Winer (2014) conclude that upwards of 60% of respondents are willing to pay such a premium and that, on average, the premium that consumers are willing to pay is 16.8%. Thus, the green segment is becoming increasingly important to firms.

Recognizing these shifts in the marketplace, firms understandably are redesigning products to include features that would appeal to green consumers. Remanufacturing is an example of a process that creates such appeal. Remanufacturable products are generally considered to be not only environmentally friendly because they lead to reduced waste by encouraging practices such as reverse logistics (Guide, 2000; Lai et al., 2013), but also profitable because they translate into lower production costs (Caterpillar Press Release, 2005; Lebreton and Tuma, 2006; Robotis et al., 2012; Sabharwal and Garg, 2013). Nevertheless, whereas the economic benefits of remanufacturing have been studied extensively, the environmental implications remain unclear. One possible reason for this ambiguity stems from reports that firms proliferated across many industries are guilty of greenwashing in the sense that they ride the wave of green consumerism without necessarily considering whether or not their actions actually benefit the environment (Orange, 2010). Thus, the interplay of how remanufacturability, on the one hand, and green consumerism, on the other hand, affect the environment requires more rigorous examination.

In this paper, we study a firm's quality design problem in a remanufacturing context given that the firm's market is defined by green consumers. More importantly, we examine the environmental consequences associated with the resulting optimal design. In particular, we investigate the conditions under which a firm designs

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its products to be remanufacturable. Accordingly, we develop a model to characterize the firm's optimal product portfolio of new and remanufactured products, and establish the corresponding optimal product design decisions. Then, we assess the environmental impact of these results. Consequently, we ascertain the extent to which profitability and environmental friendliness are complementary, and in doing so, we identify key drivers that would make remanufacturing practices more environmentally friendly.

We approach these issues by modeling a firm's quality design and remanufacturing decisions when consumers are heterogeneous in their willingness to pay for product quality. On the product design front, the firm must choose to design either a non-remanufacturable product or a remanufacturable product; and the firm must also specify the corresponding product quality, which we define as a single dimensional vertical characteristic as in Moorthy (1984). These design choices impact both the manufacturer's cost structure and consumers' valuations of the product. On the cost side, a remanufacturable product costs more to produce originally, but less to remanufacture, as compared to the cost of producing a non-remanufacturable product (Debo et al., 2005, 2006). On the consumer side, a remanufacturable product is valued more by consumers (Tully and Winer, 2014; Sengupta, 2011; Harris Interactive, 2013), as compared to the valuation of a non-remanufacturable product, but a remanufactured one is valued less (Guide and Li, 2010; Michaud and Llerena, 2011). The firm thus must consider these trade-offs and optimally choose the design and corresponding quality and price. Note that our model therefore applies to cases in which remanufacturability is an upfront decision made as part of the design process, which is true for many firms; although firms sometimes choose to remanufacture some of their product lines well after product introduction, such a case is beyond the scope of our study.

To operationalize our problem of quality design for a green market with a parsimonious model that captures remanufacturing fundamentals, we follow the lead of Ferrer and Swaminathan (2006) and Atasu et al. (2008) by formulating a two-stage analytic framework. At the beginning of stage 1, the firm first determines whether to design a remanufacturable product or a non-remanufacturable product and, correspondingly, establishes the quality of the chosen product. Then the firm sets the selling price for the product and sells an amount accordingly, as dictated by the specified consumer market's heterogeneity. Finally, to conclude stage 1, consumers who purchase the product extract its consumption value and then either discard the remains (which is the case if the product was designed to be non-remanufacturable) or return the remains (which is the case if the product was designed to be remanufacturable). The amount of re-collected remains, if applicable, thus establishes a supply constraint on the number of units that can be remanufactured for resale. Given that, at the beginning of stage 2, the firm's decision is to set its optimal product portfolio, that is, to determine how many units of new versus remanufactured products to produce and what associated prices to set accordingly for sale of each product type in stage 2.

By jointly studying quality design for a green market and product design for remanufacturability to assess and evaluate the associated environmental consequences, our model offers two benefits that constitute its primary contribution. The first benefit of our model is the incorporation of product quality as a vertical attribute in a remanufacturing context. Specifically, we formulate our model by explicitly building not only the firm's cost structure but also consumers' valuation preferences on quality. As a result, we find that, everything else being equal, the firm would couple increased remanufacturing with higher product quality. This mirrors empirical evidence that not only suggests a strong link between product quality and environmental performance (e.g., Wiengarten and Pagell, 2012; Oakley, 1993), but also suggests that consumers are interested in environmental performance and quality as interrelated dimensions of their willingness to pay (Jaffry et al., 2004). In addition, we find that product quality provides a demand lever for manipulating the product mix of new versus remanufactured products offered in stage 2. For example, if demand is not affected by quality, then the firm could reap the cost benefits of remanufacturing in stage 2 only by increasing sales of new products in stage 1 through lowering price (Yalabik et al., 2014). However, with quality dependent demand, the firm would decrease new products sales and increase product quality instead, and in doing so, the firm could charge a higher profit margin from each product without lowering price.

The second benefit of our model is the explicit inclusion of the notion of environmental impact, a quality-dependent analytical measure, to quantitatively capture the environmental consequences of designing for remanufacturability. This environmental measure provides a mechanism to assess the ecological footprint of product design and quality in a remanufacturing context. Specifically, our measure represents the total resources acquired from, and wastes discarded to, the environment during the planning horizon. Moreover, this measure is robust in the sense that various weights can be assigned to the different stages of the product life cycle without altering the insights. Perhaps most notable among these insights is that environmental impact could increase significantly if consumers are green to the extent that they value the idea that a product *can be* remanufactured but not to the extent that they also value the fact that the product *has been* remanufactured. This subtle distinction can be particularly detrimental to the environment if consumers value remanufactur*able* products on the one hand, but significantly *devalue* remanufactur*ed* products on the other hand. Given strong empirical evidence that environmentally friendly products are favored by consumers (e.g., Yoo and Kwak, 2009; Davis et al., 1995; Laroche et al., 2001) while remanufactured products are perceived as lower quality (e.g., Michaud and Llerena, 2011; Hazen et al., 2012), this somewhat counterintuitive result suggests that environmental friendliness is not necessarily a synonym for remanufacturing, and it reinforces the idea that consumption rather than production, per se, is the enemy of the environment. Thus, to paraphrase Orange (2010), the first step to a better environment is to reduce, not to recycle or to reuse.

In a similar vein, we also find that a lower production cost or a higher remanufacturing cost saving may not necessarily benefit the environment, despite increasing profit for the firm. Intuitively, a lower production cost (for new products) attracts the firm to increase the volume of new products, which thereby consumes more virgin resources and results in more discarded waste. Similarly, a higher cost saving from remanufacturing attracts the firm to design higher product quality, which again ultimately results in a more negative impact to the environment. This result is an example of Jevons paradox (Alcott, 2005). As such, it echoes discussions, many in industry journals, that warn against wholesale adoption of practices such as remanufacturing and recycling without considering industry dynamics and product properties (e.g., Volokh and Scarlett, 1997; Reich, 2004; Griff, 2003) by suggesting that it is in the interest of the environment for production technologies not to be too cost efficient.

The remainder of this paper is organized as follows. In Section 2, we review the literature and position our paper accordingly. In Section 3, we specify and discuss our model primitives, and we formulate and solve the firm's resulting profit maximization problem by mapping out and cataloging different quality design and remanufacturing strategies, we compare the different strategies to determine the firm's optimal decisions, and we explore implications accordingly. Section 4 defines the measure that we use to evaluate the impact on the environment resulting from the firm's optimal strategy. We discuss the scope and applicability of our model in Section 5, and we conclude the paper in Section 6. Proofs of propositions appear in the Appendix.