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Impact of uncertainty in the quality of returns on the profitability of a single-period refurbishing operation

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Abstract

This paper investigates how the profitability of reuse activities is affected by uncertainty regarding the quality of returned products. Specifically, we examine a reverse supply chain consisting of two collection sites and a refurbishing site, which faces stochastic demand for refurbished products in a single-period setting. The quality of returns (refurbishing yield) becomes known only after the transportation of the products to the refurbishing site. We prove that the expected profit function has a unique optimal solution (procurement and production quantities) and we derive the conditions under which it is optimal to use only one of the collection sites. The analysis is supported by numerical results which provide insights regarding the effect of the uncertain yields at the two collection sites and their correlation on optimal decisions and system profitability.

Keywords: Inventory; Reverse logistics; Random yield; Single-period; Yield correlation

1. Introduction

The field of Reverse Supply Chain Management has been gaining a lot of attention from practitioners and researchers in recent years. The increasing interest in product reuse originates not only from the reinforcement of environmental awareness and legislation but also from the fact that the engagement in reuse activities has been proven profitable in many cases. The objective of this paper is to approach a certain problem of product recovery and remanufacturing from an economic point of view and thus contribute to the research effort of identifying opportunities to increase the economic benefits from product reuse.

More specifically, the present paper investigates the impact of uncertainty in the quality of returned products on the profitability of specific reuse activities. The context is a simple reverse supply chain structure

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with a single refurbishing site (R) supplied by two collection sites, where used products are returned by consumers. Sorting and refurbishing[1] take place at location R. The refurbished products are used to satisfy the stochastic demand for such products in a single-period setting. A key feature of the problem is that the quality (refurbishability) of the returned products available at the collection cites is uncertain and may only be revealed after these products are transported, at some cost, to location R. Thus, the relevant decisions are:

- How many returned items to procure from each collection site (procurement lot sizes).
- How many of the refurbishable items to refurbish (production lot size).

The objective is to maximize the expected total profit of the entire operation.

Although the above setting may seem somewhat simplistic, it applies to several situations and types of products, either fully or closely. Specifically, refurbished products that face random demand include computers (Geyer et al., 2005), printers (Davey et al., 2005), cellular telephones (Guide et al., 2005), sun-protection products (Kuik et al., 2005). Because of the rather limited lifecycle of these products (due to technological obsolescence of electronics, short selling period and perishability of cosmetics) the single-period model can be considered a suitable approximation.

The restriction to two collection sites is admittedly partly motivated by the need to keep the analysis simple and develop insights but at the same time is realistic especially in cases where these collection sites correspond to two different streams of returns. For example, in the case of computers presented in Geyer et al. (2005) the refurbishing facility is supplied on one hand by units rejected for quality issues during manufacturing of new products and on the other hand by units returned by customers for a variety of reasons. Other examples include the cases of printers (Davey et al., 2005) and tires (Debo and Van Wassenhove, 2005) in which the two return streams refer to two different groups of returns, one resulting from a small number of major customers with large quantities of returns and a second consisting of a large number of rather small customers or end users with small return volumes.

It is worth noting that while in the case of printers presented by Davey et al. (2005) the two return streams are characterized by the same usage conditions of the returned products, this is not always the case. For example, in the systems examined by Geyer et al. (2005) and Debo and Van Wassenhove (2005) there are significant differences in the quality of returns between the two return sources (collection sites). It is not easy to obtain good estimates of the different quality levels of returned products. However, as a company goes repeatedly through the loop of new product introduction, manufacturing, sales, end-of-use returns for every product that places in the market, it can use this experience to estimate the quality of returns of each stream, at least in the form of a prior distribution of the quality level. The predicted quality levels may be correlated, since there is typically a common source of uncertainty in both return streams, due to the particular features and characteristics of the product under consideration. Our model accommodates the possibilities of quality differences and correlation between the supply sources by allowing for correlation in the yield distributions of the two collection sites.

The paper is organized as follows. The next section reviews the relevant literature and clarifies the main differences and contributions of the current paper in relation to existing work. Section 3 provides a detailed description of the problem and introduces the necessary notation. The expected profit function is formulated in Section 4; it is proved that it is concave and consequently it has a unique solution. Section 5 contains an extensive numerical investigation for the case of independent collection sites while Section 6 examines the effect of yield correlation between the collection sites both analytically and numerically. Finally, Section 7 concludes the paper with a summary and ideas for future research.

[1] We assume that the product has a simple structure and that each unit inspected and recovered retains its original identity. Alternatively, the term "product" may be interpreted as a specific (valuable) part or subassembly that is typically recovered from the product, may be refurbished or remanufactured and then used to satisfy demand for parts or may be embedded in new products. Therefore, we use the term "refurbishing" rather than "remanufacturing". For a comprehensive classification of the various recovery activities the reader may refer to Thierry et al. (1995).