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Technical Paper

Dynamic co-opetitive approach of a closed loop system with remanufacturing for deteriorating items in e-markets

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ABSTRACT

This study examines the dynamic economics of closed loop supply chains (CLSCs) that incorporate remanufacturing by developing analytical models under both cooperative and competitive policies in electronic markets. Specifically, this investigation presents the multi-variable profit-maximization problem and performs equilibrium analysis using a co-opetitive approach. Additionally, this study undertakes dynamic joint decisions for both brand-new and like-new versions of deteriorating items in a remanufacturing CLSC. The analytical results demonstrate that the dynamic co-opetitive decision depends on the potential size of the market for brand-new products, manufacturing and remanufacturing costs of the original equipment manufacturer, remanufacturing cost of the third-party independent operator, and intensity of competition between different products in the market.

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1. Introduction

Closed loop supply chains (CLSCs) (namely green/reverse supply chains) have attracted growing attention over the last two decades, from both academics and practitioners, owing to their increasing economic importance and tightening environmental legislation [1,2]. CLSCs can create enormous economic potential by recycling products and recovering added value [3]. Real world examples exist in economic analyses and case studies of various industries, including consumer electronics, printer cartridges, photocopy equipment, auto parts, aircraft engines, vehicle tanks, and others [4–11]. A recoverable goods environment is a CLSC with both traditional logistics forward flows and reverse logistics channels [6,12]. A major characteristic of the recoverable goods environment is the recoverable manufacturing system for extending product life cycles through remanufacturing and repair [13]. Guide and Van Wassenhove [2] classified reverse supply chain activities into three main categories: product return management (front end), remanufacturing operational issues (engine), and market development for remanufactured products (back end). Comprehensive reviews of CLSCs include Guide and Van Wassenhove [2], Atasu et al. [3], Fleischmann et al. [14], Zhang et al. [15], Guide et al. [16], Dekker and van der Laan [17], Inderfurth and Teunter [18], Minner and Lindner [19], and Bostel et al. [20].

Both academics and practitioners recognize the importance of remanufacturing used products as an alternative means to produce new products [21]. However, remanufacturing necessarily involves a more complex production system and supply chain than does manufacturing [22]. Remanufacturing describes the recovery of value from used goods, components and materials to yield like-new goods, where this process is performed in a manufacturing environment [16,23]. Robotis et al. [24] found that, depending on cost structure, remanufacturing collected cores may be more profitable than simply selling them “as is”. Remanufacturing is becoming increasingly prevalent, and the related literature contains numerous accounts (for example, Guide and Van Wassenhove [6]; Ayres et al. [25]; Deutsch [26]; Ginsburg [27]) of real world examples of successful and profitable remanufacturing, such as those involving BMW, Dell, General Motors, Hewlett-Packard, IBM, Kodak, and Xerox. The recovery process generally reduces use of energy and materials, and has a smaller environmental impact than manufacturing a brand-new product. Recycling and remanufacturing a core is 40–60% cheaper than manufacturing a brand-new one [28]. However, offsetting these cost advantages, a remanufactured version of the same product is sometimes perceived as lower quality, and so customers may be less willing to pay for it. Restated, remanufactured goods are frequently offered as a lower price and/or quality alternative to new goods. In various industries, such as office equipment, computer systems and auto components, remanufactured goods are ubiquitous as a means of tapping different types of market demand [25,29]. A well-designed product line, including brand-new

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and remanufactured products, may increase market share while preserving profit margins [30]. This study investigates remanufacturing operations from the manufacturer perspective. Specifically, this study looks at the case of a firm seeking to expand its market coverage by offering low-priced remanufactured goods alongside brand-new goods, where the two are substitutable.

Remanufacturing is generally cheaper when performed by a third-party independent operator (IO) than when performed by original equipment manufacturers (OEM). Arrunada and Vazquez [31] noted that economies of scale mean IO production costs are typically lower than OEM production costs. Recently, co-opetitive relationships among upstream suppliers and downstream buyers have been established in CLSC systems and examined through empirical study and analytical models. Co-opetition is a mindset, process, or phenomenon of combining cooperation and competition, based on an understanding that competitors can benefit from cooperation. Co-opetitive structure is based on game theory. Traditional business philosophy, which envisions business interactions to involve a "winner takes all" contest, is giving way to a realization that enterprises must both cooperate and compete in the networked economy. Co-opetition refers to cooperating to grow the market pie, while competing for shares of that pie [32–34]. Internet and mobile technologies have made both cooperation and competition increasingly necessary, by streamlining processes and information sharing, and thus facilitating relationships. In today's networked economy, co-opetition is a powerful means of identifying new market opportunities and developing business strategy [35]. General Mills yogurt and Land O'Lakes butter being delivered by the same trucks to the same supermarkets provides a great example of co-opetitive partnership, and allows both enterprises to achieve transport savings and higher customer satisfaction [36]. Majumder and Groenevelt [37] studied how third-party remanufacturing induces competitive behavior when remanufactured goods cannibalize demand for new goods. Debo et al. [38] examined joint technology selection and pricing decisions for brand-new and remanufactured goods, optimized remanufacturing decisions for OEM manufacturers, and extended the results to a case involving competing IOs. Additionally, Ferguson and Toktay [39] considered pricing, remanufacturing and collection decisions using the utility function approach in a scenario where an OEM faces a competing IO, and derived the cost conditions required to support profitability under monopoly and competition. Ferrer and Swaminathan [30,40] modeled optimal production quantities and prices in monopoly and duopoly environments in two-period, multi-period and infinite-horizon scenarios given a fixed production sequence. Additionally, Chen and Chang [41] investigated single-period profit-maximization with two retail prices in co-operative settings. The present study considers the occurrence of this issue between two parallel cross-channels in a CLSC that incorporates remanufacturing for decaying products. Also, the conceptual model in this provides an OEM with a comprehensive tool for effective decision-making that considers dynamic economics and strategic factors in electronic markets (EMs).

Guide and Van Wassenhove [42,43] defined CLSC management as "the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time". CLSCs are dynamic systems that evolve with customer demand and CLSC relationships. Since price has the potential to influence demand, progressive firms naturally use dynamic pricing to influence CLSC operations throughout the product life cycle. An industry survey of 2463 companies revealed that a 1% increase in price realization can improve operating profit by an average of 11.1% [44]. According to data and model assumptions, Federgruen and Heching [45] showed that dynamic pricing can increase profits by 2–6%. This contribution of dynamic pricing to increased profit is very important for industries with low profit margins, such as the retail and computer industries. Remanufacturing is a rapidly growing industrial activity without formal systems and procedures to guide dynamic management decision making. This investigation examines the problem of dynamic joint decisions under competitive and cooperative policies in CLSCs that involve remanufacturing of deteriorating goods in EMs over a multi-period planning horizon. In practice, numerous inventory items deteriorate, and are subject to depletion by factors other than demand [46]. In the United States retail sector, inventory losses from shrinkage have been high during the past 15 years, and totaled 1.59% of sales in 2006 [47]. These deteriorating phenomena are common and merit close study, particularly for CLSC management. Additionally, enterprises seek to minimize their transaction costs [48]. Theoretically, transaction costs explain why enterprises involved in a transaction favor specific transactional forms. Advances in information technology enable internet-based EMs to reduce transaction costs and simplify searches for buyers and sellers, and consequently trade channels have shifted from traditional markets (TMs) to EMs. An EM system is an inter-organizational information system that can function without a physical market. By providing an intermediary between buyers and sellers in a vertical market, such a system simplifies price and goods information exchange between buyers and sellers [49]. Electronic supply chains can enhance channel performance by increasing coordination and transaction efficiency, and by increasing the volume and velocity of information flow among channel partners [50]. EMs reportedly reduce procurement costs by up to 40% depending on industry, with an average reduction of 15% [51]. Emerging internet and EM models have indicated that business models and new technologies can resolve numerous channel issues [52]. Although problems involving remanufacturing in CLSCs have attracted significant research interest, the problem is unique in the sense that this study considers a price-dependent and time-variant demand function with substitution between new and remanufactured versions of the same goods. Restated, this investigation considers a price-setting firm that produces two product models with different variable costs and sells them at different prices to a market facing multi-variable demand. Furthermore, this study considers the dynamic characteristics and deteriorating effects, as well as the manufacturing and remanufacturing costs and competition intensity for remanufacturing CLSCs with a co-opetitive strategy in EMs. The analytical and computational results demonstrate that the dynamic co-opetitive decision over a multi-period planning horizon in EMs depends on the size of the market for new products, manufacturing and remanufacturing costs of the OEM, remanufacturing cost of the IO, and degree of competition between the two product types.

The remainder of this paper is organized as follows. Section 2 presents the problem context, assumptions, and notations. Section 3 then develops the model formulation and solution procedure. Subsequently, Section 4 compares the solutions obtained using the two methods, and analyses the sensitivity of key parameters. Finally, Section 5 outlines the research findings and presents directions for future study.

2. Problem definition

This section summarizes the underlying problem and settings, including relevant assumptions and notations. The effects of different EM business strategies on enterprise performance are illustrated using a CLSC involving remanufacturing for both brand-new and like-new versions of a single perishable product over a multi-period horizon. Using game theory, this study assumes the OEM serves as the leader, and has the power to select a competitive or cooperative policy, while the IO serves as the follower. In the former case, the OEM and IO,

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