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A Markov model of liquidity effects in reverse logistics processes: The effects of random volume and passage

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ABSTRACT

Firms at various levels of the supply chain are implementing reverse logistics systems to maximize the value captured from products flowing backwards from customers to suppliers. However, due to the sporadic and unpredictable cash outflows associated with returns, firms must take care to avoid liquidity problems. Previous work addressing reverse logistics liquidity issues has considered long-term expectations, uncertainty, and shock potential inherent in the retail reverse logistics process, but the impact of the expected returns volumes and random return quantities within fixed-scale systems has yet to be explored. The current paper addresses these concerns.

1. Introduction

The challenge of dealing with products moving backward through the supply chain is significant for modern firms, and increases in both difficulty and importance each year. The annual costs of dealing with the nearly $100 billion of returned products in the US market has been estimated as over $35 billion (Feuling, 2009; CSCMP, 2009), with consumer returns representing slightly more than half of the total (Angrick, 2009). Similarly, the value of products remanufactured into saleable form is estimated to exceed $50 billion annually in the US market (Guide and Van Wassenhove, 2003). In light of these actualities, and given the relevance of reverse logistics activities to both the firm's financial position and customer relations (e.g., Daugherty et al., 2005), the need for further research addressing reverse logistics implications for the firm has never been more vital.

Serrato et al. (2007) observe that an abundance of empirical work has already addressed reverse logistics topics from an operational standpoint, but few analytical models have been offered that adequately represent the current state of reverse logistics practice. The few exceptions have limited their focus to the implications of reverse logistics on production (Fleischmann et al., 2001; Nakashima et al., 2004) and on inventory policy (i.e., Dobos, 2003; Minner, 2001). There is a relative lack of analytic research addressing how best to manage reverse logistics product flows, especially from a financial standpoint; additional work is required that models reverse logistics from a financial perspective. The limited extant research aims to help managers better understand how to best achieve cost reductions and profit maximizations from reverse logistics activities (i.e., Kannan et al., 2009; Guide et al., 2006; Mukhopudhyay and Setoputro, 2004). However, though these models address reverse logistics outcomes from an eventual profit-and-loss perspective, they generally fail to account for a more pressing concern of the reverse logistics financial process: reversed cash flows paid out in remuneration for product returns, which are problematic to the firm due to their impact on firm liquidity in the short- to medium-term.

While the impact of liquidity as a constraint is well understood with regard to outbound inventory policy (Kashyap et al., 1994; Hendel, 1996; Carpenter et al., 1998), the relationship between reverse product flows and liquidity is less understood. While Horvath et al. (2005) examined uncertainty, shock, and long-term impacts of potential illiquidity in retail reverse logistics system, no research has yet assessed random return volumes at different supply chain echelons, nor operational and financial system design constraints. This omission in the literature is problematic. The current paper addresses these gaps in the financially oriented reverse logistics stream with a model designed to assist firms in accounting for the unpredictable quantity of returns and processing cash costs and inflows at each stage of the reverse logistics process. The model helps managers synchronize the activities of

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operations with finance to more proactively and accurately plan for short- and long-term liquidity needs, thereby better facilitating the integration of the firm's operations and finance functions.

2. Literature review: reverse logistics and firm liquidity

Reverse logistics has been termed 1 of the 5 key components of reverse supply chains (Guide and Van Wassenhove, 2003). For the purposes of this research, reverse logistics is considered to be "the process of moving a product from its point of consumption to point of origin to recapture value or for proper disposal" (Rogers and Tibben-Lembke, 1999). While this definition emphasizes the operational elements of reverse logistics for all firms, it is noteworthy that customers and suppliers engage in the process for different reasons. Customers benefit from a well-managed reverse logistics process through greater product availability and perceptions of heightened customer service, especially as the processes become more formalized (Autry, 2005; Carter and Ellram, 1998). From the supplier perspective, a successful reverse logistics program offers the firm the ability to build a closer relationship with the customer by providing additional opportunities to serve and satisfy them (Barsky and Ellinger, 2001). An additional supplier benefit is that worn out or obsolete products can be remanufactured and resold, thus allowing for the achievement of additional margins (Heese et al., 2005, Stock et al., 2002).

The reverse logistics process was initially described by Rogers and Tibben-Lembke (1999) and is illustrated in Fig. 1. As can be seen from the figure, products pass through a number of states upon their return, including a gatekeeping function, various forms of processing and/or sorting and processing, and an eventual disposition state that is either internal or external to the firm.

However, the aforementioned benefits come with associated challenges, specifically the expenses associated with managing reverse logistics process complexities (Skinner et al., 2008, Amini et al., 2005). Dowlatshahi (2005) identifies five strategic factors essential for designing and implementing successful reverse logistics systems, one of which is financial costliness. Addressing short-term costs with liquid assets is a primary concern in the current research, given the importance of cash in facilitating the firm's ability to shoulder short-term reverse logistics costs. The current article adopts a liquidity management perspective in examining reverse logistics operations.

Liquidity management is defined as the ability of the firm to manage its short-term resources and obligations, for the purposes of tracking the amount and timing of cash inflows and outflows (Gentry and De La Garza, 1990), and provides "early warning of problems ahead … to prevent illiquidity while creating corporate value" (Badell et al., 2005). Firm underinvestment in inventory due to liquidity pressures can lead to stock-outs, thereby negatively affecting performance (Pirtilla and Virolainen, 1992). Calomiris et al. (1995) found that firms with limited access to financial instruments place greater pressure upon their inventory to account for liquidity shocks, and Tribo (2007) shows that differing ownership structures' affect upon liquidity also impacts inventory levels. Sodhi and Tang (2009) incorporate liquidity in supply chain planning in the face of demand uncertainty but do not address the impact to liquidity of the reverse flows. Given that returns-based cash outflows can tie up liquidity just as other cash flows can, the impact of the reverse process upon liquidity merits further examination.

Horvath et al. (2005) applied Markov chain analysis to assess the liquidity impact of product returns on the retail reverse logistics process. However, they failed to address the random nature of product returns, limited returns to levels matched to capacity, and failed to consider cost variation due to returns process utilization. This article addresses these shortcomings, leading to increased ability to plan for liquidity shocks that the reverse flows of product can create. In summary, although limited work has analyzed liquidity within the reverse logistics area, the current model helps by assisting firms in making provisions for liquidity needs, by including provisions for uncertainties and potentials for shocks not only in the reverse logistics process but also for variations in number of returns, and cash outflows at each stage of the process. This model allows firms to better plan for longer-term liquidity needs, especially given the dynamic nature of the returns process and the varying nature of its associated costs.

3. Liquidity effects of reverse logistics model

3.1. Process and capacity

Our modeling of liquidity assessment includes an analysis of the number of returns, the process that these returns follow through the reverse logistics system until they are finally removed, and the cash flows associated with these dynamics. We first model the reverse logistics process, then incorporate the number of returns, and finally include cash dynamics.

The process impacts of reverse logistics on firm liquidity, considered independent of the number of returns at any given time, begin with a periodic classification of a returned unit as being in state i, s_i: $i=(1, 2,\ldots,T)$, such that T is the number of transient, or processing, states depending upon the unit's status. Similarly, a unit may be classified in an absorbing state, s_k: $k=(\text{I}, \text{II},\ldots,K)$, where K is the number of absorbing states or ways the unit can leave the process. Associated with these states are transition probabilities: $r_{i,k}$: $i=(1, 2,\ldots,T)$, $k=(\text{I}, \text{II},\ldots K)$ are the

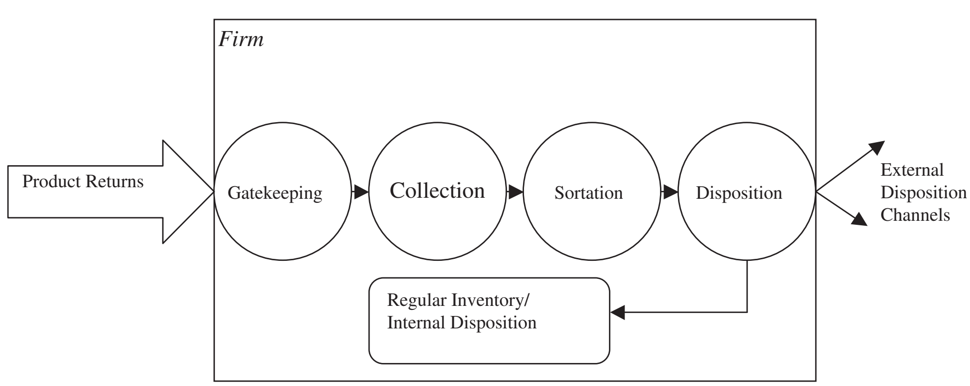

Fig. 1. The firm-level reverse logistics process.