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Redesigning a closed-loop supply chain exposed to risks

Johan F. Lundin *

Department of Industrial Management and Logistics, Lund University, SE-22100 Lund, Sweden

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ABSTRACT

Supply chain management includes coordination and motivation of independently operating partners. Therefore, it is important to align logistics structures, processes and incentives, especially when making major changes involving those components. Traditionally, cost, quality, and service have served as prioritized performance indicators for supply chains, but lately risk is also taken into consideration (Tang, 2006), especially when studying risk-exposed supply chains.

This paper presents a case study of a cash supply chain (CSC). A CSC provides society with notes and coins (Rajamani et al., 2006), which typically involves two parties working together: a central bank and a group of private actors (private banks and logistics service/security providers). Together, they form a closed-loop supply chain (see Guide and Van Wassenhove, 2006), which through their storage facilities and transport means supply cash to their customers (ATMs, bank branches, and retailers), whom in turn enables society's cash consumption. The CSC studied in this paper has during the last couple of years gone through several design changes in network structure (e.g. reducing number of storage facilities), processes (outsourcing), and incentive mechanisms (payment schemes and policies). Most design changes were carried out in order to decrease number of transports from and to central bank storage facilities, nevertheless some of them led to unintended effects (so-called misalignments). Therefore, the purpose of this paper is to present a model that determines effects caused by design changes in a CSC.

1. Introduction

Supply chain management includes coordination of independently operating partners, which is important to take in consideration when planning and designing operations. In short, a supply chain consists of network structures, processes, and management components (Lambert et al., 1997), which together determine its performance including operational costs and service. Lately, risk costs are also taken into consideration when designing the supply chain (Tang, 2006). For example, a recent review on supply chain risk management found that risks taken into consideration typically are related to disruptions or some type of business risk (Tang and Nurmaya Musa, in press). However, few papers have considered antagonistic risk, which could be defined as deliberate, illegal, and hostile risk. A supply chain with high interest to society facing this type of risk is the cash supply chain (CSC), which provides society with notes and coins (Rajamani et al., 2006). It typically consists of two parties: a publicly owned central bank and a group of private actors (private banks and logistics service/security providers). Together, they form a closed-loop supply chain (see Guide and Van Wassenhove, 2006), which includes both a forward and a backward flow of cash using storage facilities and transport means to distribute cash to their customers (ATMs, bank branches, and retailers). During the last couple of years, the Swedish CSC has attempted several design changes in (i) network structure (e.g. reducing number of storage facilities), (ii) processes (e.g. redesign of activities), and (iii) incentive mechanisms (e.g. payment schemes and policies). Most changes were carried out in order to decrease number of transports to and from central bank storage facilities, unfortunately some of them led to unintended effects. Previously, Lundin and Norrman (2010) presented a framework for describing and analyzing changes in a CSC's structure, processes, and incentives. However, this framework was not developed for quantifying the associated effects, which is why the purpose of this paper is to present a model that determines effects caused by design changes in a CSC. This involved developing a model that captures network structure, processes, and incentives for quantifying costs, as well as a function for quantifying risks, based on a case study of the Swedish CSC. Focusing on costs and risks related to private actors in the CSC introduces a commercial perspective for analyzing changes in a CSC, which opens up for discussing central bank concerns such as privatization. The remainder of this paper is organized as follows. First, we discuss literature relating to this paper. Next, the Swedish CSC and its past design changes are introduced. Based on data from the Swedish CSC, a time-expanded network model is developed with a risk evaluation

* Tel.: +46 46 222 3116; fax: +46 46 222 4615.
E-mail address: johan.lundin@tlog.lth.se

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function for each part of the network. Then, the supply chain design changes are analyzed from a cost and antagonistic risk perspective using the network flow model and the risk function. Finally, conclusions are drawn and results discussed.

2. Literature review

According to Guide and Van Wassenhove (2006), the design of a closed-loop supply chain also encompasses the return flow, which can be facilitated through the original forward channel, through a separate reverse channel, or through combinations of the forward and the reverse channel (Fleischmann et al., 1997). Interestingly, closed-loop supply chains are especially suitable for products with high value, low remanufacturing costs, and low incremental costs (Debo et al., 2005), which coincidently are characteristics describing the CSC. When designing closed-loop supply chains, several decisions must be made pertaining to structure and processes: e.g. what organizations should be included in the reversed distribution (Guiltinan and Nwokoye, 1975), what activities are included and where (Pohlen and Farris, 1992), and what the relation is between forward and reverse distribution (Fleischmann et al., 1997). When it comes to what organizations to include, it is suggested that retailers should take responsibility for collecting the returned products in order to properly benefit from remanufacturing (Savaskan et al., 2004). Guide and Van Wassenhove (2009) stress that incentives are of great importance when designing a closed-loop supply chain, since it typically has an increased number of players (e.g. third-parties) with information asymmetries and incentive misalignments in the reverse supply chain. Hence, the recent research results related to these issues. For instance, it is shown that a shared-savings contract aligns incentives between a tire remanufacturer and a fleet operator creating a win–win situation (Yadav et al., 2003) and that a manufacturer introducing a rebate incentive on unreturned products to its retailers reduces total number of returns (Ferguson et al., 2006). These contributions have in common that they focus on a specific part of the closed-loop supply chain (e.g. return flow), whereas contributions encompassing a more comprehensive perspective including the forward and return flow as well as the supply chain's structure, processes, and incentives are missing. Previously, Rajamani et al. (2006) presented a framework for analyzing CSCs, which can be used for developing managerial insights relating to the design of a CSC. This was extended by applying inventory control principles to the CSC context, which shed light on how banks in the United States should cope with recent policy inventory policy changes by the U.S. Federal Reserve (Geismar et al., 2007). When it comes to incentives in a CSC, previous research shows that the introduction of cash recirculation incentives for private banks reduces returns to the U.S. Federal Reserve (Dawande et al., 2010). These contributions have in common that they apply a societal perspective to the CSC, where managerial insights are based on costs associated with a central bank cash operations, so-called societal costs. However, one could argue that a more strategic perspective on reducing central bank costs would be to privatize the CSC, where it would be open for commercial actors to compete with the most cost efficient supply chain. Another societal perspective include risk costs associated with handling cash, which is discussed briefly by Lundin and Norrman (2010). When it comes to analyzing risks associated with handling products, there is a rich literature pertaining to transportation of hazardous materials that expound on this issue. For instance, Erkut and Gzara (2008) uses a network flow model for designing risk-exposed supply chains that transports hazardous materials. This topic has also been treated from a closed-loop supply chain perspective with focus on the design of transportation networks for hazardous material (Batta and Chiu, 1988; Caruso et al., 1993). Even though research focused on closed-loop supply chains typically includes some kind of remanufacturing (Guide and Van Wassenhove, 2006), there are contributions focusing on a closed-loop service network (Kusumastuti et al., 2008). These supply chains have features resembling to the CSC, which can be considered as a special case of a closed-loop supply chain where products (e.g. cash) are recycled and processed for redistribution.

3. The Swedish cash supply chain

Due to a series of sensational and violent attacks on the Swedish cash supply chain (CSC) during the year of 2005, the Commercial Employees Union in Sweden decided to temporarily stop all cash transports. This resulted into a nationwide shortage of cash in ATM machines. Although, it is the companies transporting the cash that are attacked, the whole chain got affected and especially the central bank. The central bank has, by law, the responsibility to deliver cash efficiently and safely to the society. Some central banks have recently followed supply chain design patterns of other industries like centralized distribution (compare to Abrahamsson et al., 1998), redesigning processes, and shifting liabilities (e.g. logistics outsourcing to third party logistics). The Swedish central bank has outsourced their cash supply processes to private actors, which include cash-in-transit (CIT) companies (e.g. Loomis and G4S) and private banks. Over time, they have developed parallel and competing structures increasing their operative and logistical role in the CSC and ultimately decreasing the central bank's operative influence.

3.1. Closed-loop supply chain

The central bank has monopoly on issuing cash, which means that supply originates from their storage facilities. The supply chain actually originates at the cash manufacturers from which the central bank procures all notes and coins. In most CSCs, this part of the process tends to be highly controlled and protected by the central bank and can therefore be viewed as an integrated unit. Since the central bank has huge volumes of cash in their storage facilities, one can assume that their supply capacity is unlimited. Today, there are two central bank storage facilities in Sweden, which are able to stock, process, and destroy cash. From central bank storage facilities, CIT companies currently collect cash, which they transport to privately run storage facilities called depots. When cash leaves a central bank facility and enters the private sector, it obtains full face value from an accounting perspective. Because of inflation, the value of cash diminishes over time entailing an opportunity cost. Currently, there are 11 depots owned and shared among the large banks in Sweden (Nordea, Handelsbanken, Swedbank, SEB, and Danske Bank). This means that inventory can be shared among the members of the supply chain. Just as the central bank storage facilities, depots are able to store and process cash for redistribution. However, they are not allowed to destroy cash that is unfit for circulation, which means that it has to be transported back to the central bank once the cash becomes unfit for recirculation. On average, 25% of the outstanding cash volume per year is deemed unfit. However, as long as the cash is fit, it can be recirculated through the private part of the CSC, which include depots, cash counting facilities (CCF), terminals, and customers. A CCF can be compared to a depot, except it is not shared between members. Currently, there are 17 CCFs owned and operated CIT companies. They also utilize terminals (11 in Sweden), which can be compared to cross-docks (consolidation points for relatively large geographical areas). These facilities can neither store nor process cash. Finally, typical