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A two-period game of a closed-loop supply chain ☆

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ABSTRACT

We consider a two-period closed-loop supply chain (CLSC) game where a remanufacturer appropriates of the returns' residual value and decides whether to exclusively manage the end-of-use product collection or to outsource it to either a retailer or a third-service provider (3P). We determine that the manufacturer outsources the product collection only when an outsourcee performs environmentally and operationally better. On the outsourcees side there is always an economic convenience in managing the product returns process exclusively, independently of returns rewards and operational performance. When outsourcing is convenient, a manufacturer always chooses a retailer if the outsourcees show equal performance. Overall, the manufacturer is more sensitive to environmental performance than to operational perfomance. Finally, there exists only a small region inside which outsouring the collection process contributes to the triple bottom line.

1. Introduction

Suppose that a manufacturer can derive some economic benefits from the used products it previously sold to consumers, and that the latter are willing to recycle them. This raises the following relevant question: should the manufacturer outsource the collection activity or do it itself? The aim of this paper is to characterize the conditions under which the manufacturer is better off outsourcing and to assess its impact on potential stakeholders, on consumer's surplus and on the environment.

A closed-loop supply chain (CLSC) combines forward and reverse activities into a unique system, to improve economic and environmental performance (Krikke, Le Blanc, & van de Velde, 2004). Forward activities include new product development, product design and engineering, procurement and production, marketing, sales, distribution, and after-sale service, while reverse activities refer to all those needed to close the loop, such as product acquisition, reverse logistics, points of use and disposal, testing, sorting, refurbishing, recovery, recycling, re-marketing, and re-selling (Fleischmann, Krikke, Dekker, & Flapper, 2000; Guide & Van Wassenhove, 2009). A necessary condition for firms to close the loop is that producing with used components is less costly than manufacturing with new materials (Guide & Van Wassenhove, 2001; Savaskan, Bhattacharya, & Van Wassenhove, 2004). Several empirical studies (see, e.g., Fleischmann, van Nunen, & Grave, 2003; Tabolt, Lefebvre, & Lefebvre, 2007) have already highlighted the relevance of CLSC for business and government. The reviews in Fleischmann, Bloemhof-Ruwaard, Dekker, van der Laan, and Van Wassenhove (1997), Dekker, Fleischmann, and Van Wassenhove (2004) and Atasu, Guide, and Van Wassenhove (2008a) provide a comprehensive report on what has been achieved so far, and on the issues that still need attention.

In a common form of a CLSC, a manufacturer collects used products and appropriates the benefits. In this case, the manufacturer must create a proper incentive for customers to return products. Lexmark started the "Prebate" program in 1998, where customers could get 30$ rebate off a 230$ toner cartridge if they return the cartridges back (Majumder & Groenevelt, 2001). Similarly, Hammond and Beullens (2007) show that a buy-back mechanism can ideally supply a 100% return rate. When gains from the collection process are high, manufacturers prefer collecting by themself (De Giovanni & Zaccour, 2013). For instance, Guide (2000) reports that 82% of firms collect directly from customers. Xerox carries out alone the product collection process and performs 65% return rate Guide (2000). In such a context, the other players (e.g., the retailers) do not participate in managing the backward flow, because either they do not have the right logistics system in place, or because the residual value of returned products is too low. However, this does not mean that other forms of CLSC could not develop. Indeed, several reasons may induce manufacturers to involve other parties (Klassen, 2009). Because they are closer to consumers, retailers may be able to achieve a higher return rate than manufacturers. Similarly, third-party service providers (3P) may exploit their specialized skills to better perform all CLSC operations. There is ample evidence from the literature that choosing the right CLSC

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configuration is crucial to its success. Savaskan et al. (2004) obtain that a CLSC performs better when the retailer manages the product acquisition. Bhattacharya, Guide, and Van Wassenhove (2006) model a three-player game where a manufacturer always does the collection. Depending on the type of contract used, there are several coordination mechanisms that may align the players' goals. De Giovanni and Zaccour (2013) show that when the manufacturer and the retailer share the cost in investing in green activities aimed at increasing the return rate, both players could be better off in a large region of the parameter space. De Giovanni (2011a) demonstrated that players cooperate in a CLSC only when the collector receives a sufficiently high incentive.

When outsourcing the product collection, the manufacturer clearly needs to design adequate incentives to induce the other players to collaborate or achieve better results (Corbett & Savaskan, 2003; Ferguson & Toktay, 2006; Majumder & Groenevelt, 2001). For instance, ReCellular uses a variety of incentives and sources to collect used phones from cellular airtime providers, third-party collectors, etc. (Guide, Jayaraman, & Linton, 2003). Kodak offers customers and retailers some economic incentives to return their cameras because components can be used to produce new products (Savaskan et al., 2004). Interface Inc. is the world's largest provider of commercial carpet tile that leases carpets instead of selling them; the ownership of off-lease products gives Interface Inc. an incentive to recover the residual value of these products (Agrawal & Tokay, 2009). Pitney-Bowes remanufactures off-lease products by offering a trade-in program (Ferguson & Toktay (2006)). Similarly, Xerox obtains part of its returns from trade-ins, which has resulted in cost savings of several hundred million dollars per year (Ray, Boyaci, & Aras, 2005). Consequently, the manufacturer's decision to manage the return process either exclusively or jointly with other players depends on several factors (Hammond & Beullens, 2007), such as building up an appropriate incentive. The theoretical literature general reports models that characterize exogenous incentive mechanism because it allows players to know in advance both the costs and benefits of closing the loop. manufacturers have interests to align the incentives for closing the loop because other suppliers do not take part of the collection process (Guide & Van Wassenhove, 2009). Bakal I.S. and Akcali, 2006 demonstrated than when the per unit acquisition price is exogenous rather than endogenous, the manufacturer experiences better operational performance as the order quantity equals the production capacity. Nevertheless, the authors showed that an endogenous incentive mechanism is a suitable scenario as well. Savaskan et al. (2004) and Savaskan and Van Wassenhove (2006) cited the case of Kodak that reimburses a fixed fee to retailers per each unit returned. They used the same incentive scheme to show that manufacturers always prefer outsourcing to retailers. De Giovanni (2011b) introduces an exogenous incentive mechanism that takes the form of reverse-revenue-sharing contract; he shows that the incentive along with the transaction costs influence the chain coordination. Corbett and DeCroix (2001) examine exogenous shared-savings contracts to overcome incentive conflicts between a supplier and a buyer to reduce the use of indirect materials. Ferguson and Toktay (2006) model an endogenous incentive that assumes the form of a target rebate; the mechanism increases the retailer's wishes to invest more in green activity programs and perform the reverse flow management. Majumder and Groenevelt (2001) propose an endogenous incentive to increase the fraction of remanufacturable products available and decrease the costs for remanufacturing. Guide et al. (2003) model the case of an endogenous acquisition price: the decision maker has to decide a combination of acquisition prices according to the quality of different returns in order to maximize its profits. Returns are stimulated through price incentives. Similarly, Ray et al. (2005) use an endogenous price mechanism in the form of trade-in rebate to drive customers' willingness to repurchase. De Giovanni and Zaccour (2013) model a cost-revenue sharing contract in which the incentive has an exogenous component (linked to revenue sharing) and an endogenous component (linked to sharing costs). Robotis, Boyaci, and Verter (2012) make the simplifying assumption that no incentive is provided neither to collectors or to customers because all past sold products will be surely received back.

In this paper, we characterize and compare the equilibrium results of three scenarios, namely, where the manufacturer exclusively manages product returns, outsources the activity to its retailer, and where it outsources it to an external service provider. We develop these three scenarios because in the world of business manufacturers always struggle with decisions on whether the product collection process should be outsourced. For instance, Valpak and Batteries Plus have recently internalized the reverse logistics management. In Sainsbury, Valpak (2011) has decided to work with retailers rather than with 3PL on the battery collection process until 2010. Then, during 2010, the company has started to personally manage the house hold battery collection process to improve the return rate. Similarly, BatteryPlus Ltd., who outsourced the battery collection through a 3PL until 2011, has decided to directly manage the collection process because outsourcing was not economically and operationally efficient. The company invested in reverse logistics network and information systems to internalize all return activities in 2012 (HighJump Software, 2012). As the return process is inherently dynamic, our model is also. For each scenario, we build a two-period game, in which some of the units sold in the first period are returned to the manufacturer in the second period. Further, we assume an active approach to recycling by considering that the entity in charge invests in certain activities to influence the return rate. Our model is a dynamic extension to the static game by Savaskan et al. (2004) (SVB), who recommended an analysis of strategies and outcomes in a dynamic CLSC. As we will see, our results substantially differ from whose obtained by SVB in a static setting.

Our results indicate that independent of the selected CLSC structure, closing the loop is always beneficial for all players comparatively to the case when the management of reverse activities is not part of the business. The collection of products increases the internal efficiency of the manufacturer creating the basis for a lower double marginalization effect which implies lower wholesale prices, higher demand and, consequently, higher profits. In the comparison between chain configurations, all parties with a stake in the choice of the CLSC structure, i.e., the manufacturer, the consumer and the environment, prefer in a large region of the parameter space that the manufacturer be the one to close the loop and collect the used products. Nevertheless, the cost differences among players is just less important in the selection of the CLSC structure. The manufacturer is more sensitive to environmental performance (environmental effectiveness) than to operational performance (collection efficiency). Thus, it will always make use of outsourcing when the outsourcee is able to better perform the environment, while on the cost side outsourcing is a valid option only when the manufacturer's collection process is drastically inefficient. On their side, both the retailer and the external service provider would be better off, profit-wise, to perform this task themselves, but they will be asked to do so by the manufacturer only when it is itself less efficient either in terms of collection cost and/or influencing the return rate. The same conditions apply for sales in the first period, that is, outsourcing is prefarable in few cases, with a preference when outsourcee's environmental performance is higher.

We obtain different results in the evaluation of outsourcing to perform the environment, that is, the return rate. Our findings show that conditions for choosing outsourcing are much more stringent for both environmental and operational performance. The leader will opt for outsourcing conditioned to substantially