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Incentive strategies for an optimal recovery program in a closed-loop supply chain[☆]

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ABSTRACT

We consider a dynamic closed-loop supply chain made up of one manufacturer and one retailer, with both players investing in a product recovery program to increase the rate of return of previously purchased products. End-of use product returns have two impacts. First, they lead to a decrease in the production cost, as manufacturing with used parts is cheaper than using virgin materials. Second, returns boost sales through replacement items.

We show that the coordinated solution can be implemented by using so-called incentive strategies, which have the property of being best-reply strategies if each player assumes that the other is also implementing her incentive strategies. A numerical example illustrates the theoretical results.

1. Introduction

Improving the performance of a closed-loop supply chain (CLSC) with respect to what it can achieve when the different agents act selfishly, has been the topic of a significant literature during the last two decades or so. In a recent survey of CLSC literature, Souza (2013) classifies the research into four topics, namely: (i) types of incentives; (ii) time-dependency of returns; (iii) waste vs. active return policy; and (iv) firms' motivations to close the loop. In this paper, we implement incentive equilibrium strategies in a dynamic setting to coordinate a CLSC made up of one manufacturer and one retailer, with both agents being actively involved in product return and recovery policy. Our contribution therefore falls under topics (ii)–(iv).

The use of incentive strategies allows us to embed the coordinated solution, that is, the jointly optimal payoff, with an equilibrium property. This means that each player will find it individually rational to implement over time her part of the cooperative solution rather than deviating to a noncooperative strategy. By closed loop, we essentially refer to the return by (some) consumers of past-purchased products. We note from the outset that we focus on the returns of end-of-use products and disregard commercial returns. End-of-use products are goods that have been intensively used over a period of time and may be returned so that some of their components can be used in manufacturing new items (Guide & van Wassenhove, 2009). Commercial returns are products that have barely been used and can be reintroduced quickly onto the market (Guide, Souza, van Wassenhove, & Blackburn, 2006). Whereas companies may be interested in collecting end-of-use products for remanufacturing purposes, they generally try to avoid costly commercial returns (Ferguson, Guide, & Souza, 2006).[1]

We consider the following two motivations for the supply chain to close the loop: (i) cost savings, as producing with used materials or parts extracted from returned products is cheaper than manufacturing with new materials; and (ii) demand expansion, as consumers who return their used products are likely to replace them with new ones. While there are empirically observed situations in which consumers who return/recycle products also buy new ones, this marketing aspect of recycling and remanufacturing has been largely overlooked by the CLSC literature. Indeed, research has focused on operational aspects aimed at improving the economic performance, more specifically on cutting costs through the remanufacturing of returns rather than using new raw materials (see, e.g., Savaskan & Van Wassenhove, 2006; Savaskan, Bhattacharya, & van Wassenhove, 2004). Put differently, the implicit assumption has been that neither

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[1] There is a significant literature dealing with different issues related to the control of the flow of commercial returns; see, e.g., Pasternack (1985), Davis, Gerstner, and Hagerty (1995), Padmanabhan and Png (1997), Tsay (2001), Ferguson and Tokay (2006), Su (2009) and Shulman, Coughlan, and Savaskan (2010).

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the return rate nor the advantages of remanufacturing exert an impact on demand, which has mainly been modeled as a function of price only (see, e.g., Atasu, Guide, & van Wassenhove, 2008a; Atasu, Sarvary, & van Wassenhove, 2008b; Bakal & Akcali, 2006; De Giovanni & Zaccour, 2013, 2014; Debo, Toktay, & van Wassenhove, 2005; Ferguson & Tokay, 2006; Ferrer & Swaminathan, 2006; Guide, Jayaraman, & Linton, 2003; Hammond & Beullens, 2007; Robotis, Bhattacharya, & van Wassenhove, 2012; Savaskan & Van Wassenhove, 2006; Savaskan et al., 2004). A first contribution of this paper is in accounting for both the operational (cost-saving) and marketing (demand-expansion) potential benefits of remanufacturing in a dynamic model of a CLSC.

As regards product return policies, firms can follow either a passive (waste) or active (market-driven) approach. In a waste return approach, the product recovery system is considered a cost center, with returned products typically being old and of poor quality. Consequently, the recovery options for these products are often limited (Dobos, 2003). Generally speaking, the assumption in the waste-return-approach literature is that the return rate is a given parameter or a realization of a random variable, that is, independent on the firm's decisions; see, e.g., Atasu et al. (2008a, 2008b); Dobos (2003) Ferrer and Swaminathan (2006) Minner and Kleber (2001). In an active return policy, firms invest in some activities to increase the return rate. Guide and van Wassenhove (2002) provide a framework for the market-driven product acquisition system to effectively control product returns, especially product quality. Guide et al. (2003) propose a price-incentive scheme aimed at consumers to enhance product returns. In Savaskan et al. (2004) and Savaskan and Van Wassenhove (2006), companies invest in promotional activities to boost the return rate. Debo et al. (2005) equate the return rate to the remanufacturability level, which is the fraction of sold products that can be remanufactured after one period of use. In De Giovanni (2014) and De Giovanni and Zaccour (2013), the return rate is linked to the green activities undertaken by the manufacturer. In this paper, we also adopt an active approach to returns. However, we depart from the literature (and contribute to it) by assuming that both members of the CLSC, i.e., the manufacturer and the retailer, invest in a product recovery program (PRP) that aims at increasing returns by consumers. The rationale behind involving both players in a PRP is that returned used products affect not only (re)manufacturing cost, but also demand and consequently both players' revenues. One reason often cited by the literature to explain used products returns is that consumers want to repurchase greener products (see, e.g., Han, Hus, & Lee, 2009; Ko, Hwang, & Kim, 2013). In such context, there is an easy case for marketing that invites consumers to even anticipate their rebuys.

When the main purpose of product recovery is reducing production costs, then the benefits go to the manufacturer, and the retailer has no direct incentive to contribute to a product recovery program. Of course, one can argue that if the production cost is lower, then this will be reflected in a lower wholesale price, resulting in the retailer also benefiting from product recovery. In any event, when returns boost demand in the retailer's outlet, then it becomes crystal clear to that player that it is in her best interest to participate in a PRP to increase the return rate. Now, although both members of the CLSC are interested in the PRP, this does not imply that the manufacturer and the retailer will choose the optimal investment levels that would maximize the total chain profits. To increase the players' contributions in a decentralized supply chain, one needs to implement some incentive schemes. Here, the literature has focused on per-return incentives, that is, the collector (manufacturer, retailer or third party) receives a per-return amount, which is often an exogenous parameter. References in this area include, e.g., Corbett and DeCroix (2001), Majumder and Groenevelt (2001), Fleischmann, van Nunen, and Grave (2002), Savaskan et al. (2004), Ray, Boyaci, and Aras (2005), Bakal and Akcali (2006), Savaskan and Van Wassenhove (2006), and De Giovanni and Zaccour (2013) 2014). Other types of incentive schemes have been developed that depend on other features, such as the product acquisition price through a buy-back mechanism (Hammond & Beullens, 2007; Kogan & Tapiero, 2007), and the players' efforts and CLSC performance (De Giovanni, 2015).

A CLSC is a dynamic phenomenon and we believe it should be studied as such. Consumers purchase a product today and return it in the future; therefore a dynamic approach should be used when investigating CLSC problems. This claim finds confirmation in the paper by De Giovanni and Zaccour (2014), who demonstrate that, when using a per-return incentive mechanism to coordinate a CSLC while shifting from a static to a two-period model, the suitability of that coordination mechanism is not always granted as it is in a static setting (e.g., Savaskan et al., 2004). Ray et al. (2005) evaluate profits and pricing policy under both time-dependent and time-independent scenarios–namely, age dependent and age-independent differentiation–and show that remanufacturing success substantially changes under non-static models. Similarly, Minner and Kiesmuller (2012) present both a static and a dynamic product acquisition policy to show that a static model can only be used as a basic representation of the findings, which should then be evaluated in a dynamic setting. Moving from a single-period to an infinite-period dynamic programming model, Debo et al. (2005) investigate the impact of cost parameters, consumer profiles, technology choice and industry structure on the profitability of remanufacturing in a dynamic setting. Debo, Toktay, and van Wassenhove (2006) extend the results in Debo et al. (2005) by proposing a Bass diffusion model with repeat purchases in a remanufacturing context. They show that remanufacturing is more attractive for slowly diffusing products and that a single-period analysis limits the investigation of the overall problem. Although the use of dynamic models seems somehow natural, previous research in CLSC has focused either on static (e.g., Aras, Boyaci, & Verter, 2004; Savaskan & Van Wassenhove, 2006; Savaskan et al., 2004) or on two-period games (e.g., Atasu and Çetinkaya, 2006; Ferrer and Swaminathan, 2006; Majumder and Groenevelt, 2001), while dynamic models have been rarely used (e.g., De Giovanni & Zaccour, 2013; De Giovanni, 2014; 2015; Robotis et al., 2012).

We model the CLSC as a two-player dynamic game and show that incentive strategies lead to the implementation of the joint optimal solution. The manufacturer chooses the wholesale price and her investment in the PRP, and the retailer selects the price to consumers and also invests in the PRP. The idea of implementing some form of incentive strategy in dynamic supply chains (or marketing channels) has previously been discussed by Jørgensen and Zaccour (2003a, 2003b) and Jørgensen, Taboubi, and Zaccour (2006). In these papers, the (dynamic) pricing and remanufacturing were not an issue and, in Jørgensen et al. (2006), the incentive game was one-sided, that is, there was a leader in charge of designing the incentive. In our setting, we have a two-sided incentive problem. The implementation of dynamic incentive strategies in a CLSC to reach the collectively optimal outcome is, to the best of our knowledge, new in the literature.

The rest of the paper is organized as follows. Section 2 introduces the models and notations. Section 3 characterizes the equilibria in those models and presents some results. Section 4 presents a numerical simulation to compare strategies and profits, and discusses some managerial implications. Section 5 provides some concluding remarks and suggestions for future research.

2. Model

We consider a closed-loop supply chain (CLSC) composed of one (re)manufacturer, player M; and a retailer, player R. Time t is continuous and the planning horizon is $[0, \infty)$. The manufacturer chooses the wholesale price, $\omega(t)$, and the retailer fixes the retail price to consumers, $p(t)$. Both players are actively engaged in a product recovery program (PRP) whose objective is to induce consumers to return previously purchased products. The rationale of the PRP is twofold. First, investments in a PRP have a marketing purpose, since consumers