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Transition inertia due to competition in supply chains with remanufacturing and recycling: A systems dynamics model

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ABSTRACT

This paper studies the link between capital goods supply chains and sociotechnical transitions. Research on the latter has so far tended to focus on sustainability, energy and transport systems. Despite the considerable shift from products to services, supply chains are an integral element of most sociotechnical systems and there seems to be no foreseeable substitute for them. Consequently, for transitions to sustainability to take place, the inertia of supply chains in these systems has to be overcome and their environmental impact reduced. The paper explores this with a system dynamics model of a supply chain. While remanufacturing of used products by the retailer and recycling by the supplier can reduce the environmental impact of the supply chain, competition in the market between new and remanufactured products forces them into a situation where improving business and environmental performance is difficult.

1. Introduction

There is a considerable amount of research on sociotechnical system transitions with an emphasis on transitions to sustainability (Geels, 2011). A particular focus has been placed on energy and transport systems that cater for a considerable number of everyday human needs. Despite the shift from products to services of modern industrial systems (Oliva and Kallenberg, 2003; Kastalli and Van Looy,

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2013) supply chains are needed to satisfy individual consumer and business needs through capital and consumer goods. Inevitably supply chains being part of a sociotechnical system, they also contribute to its inertia. Therefore a transition towards sustainability requires that the operation of supply chains (micro level) be altered as well towards modes of operation with lower carbon emissions, material disposal and environmental impact. These alternative operational modes are referred to in the literature as "green" supply chain or closed loop supply chains (Guide and Van Wassenhove, 2009; Sarkis et al., 2011). The importance of supply chains as integral elements of sociotechnical systems implies that the relevance of their operations and operations strategies for transition processes must be explored.

The present article provides a first step in this direction. It explores a supply chain where in the forward channel Original Equipment Manufacturers (OEM) cooperate with retailers in selling brand new products and compete with them in the reverse channel when the latter start remanufacturing used industrial products and reselling them (e.g. electric motors, tires, appliances). Remanufacturing entails bringing used products back into an "as good as new" condition through the processes of disassembly, overhaul and replacement operations (Fleischmann et al., 1997). The supply chain is assumed to operate in a sociotechnical regime, as an intermediary between its technical and social system elements that supply a societal need. Operating in a competitive, profit making, business environment, the OEM has to respond in a competitive way to maintain its brand (new) product market segment against an expanding segment for remanufactured products. In both segments customers seek product functionality, which is an increasingly relevant consideration in a transition to a circular economy context (Ellen MacArthur Foundation, 2012).

Investigating how a single OEM and a retailer compete in supplying the market with new and remanufactured products, is analogous to analysing how a small niche with potentially reduced environmental impact can form in isolation from the rest of the regime. A system dynamics model (Sterman, 2000) is developed where competition in the supply chain is conceptualised using the Resource Based View (Barney, 1986). A range of OEM strategic responses to competition from remanufactured products is analysed, such as acting preemptively and recycling used products or improving its production processes. It is assumed that facing the well-known "exploration vs exploitation dilemma" (March, 1991), the OEM commits to strategies that allow him to exploit his current resources rather than develop and explore the possibilities offered by new ones. The model is used to answer the following questions:

1. What is the effect of response strategies for the OEM?
2. Are the OEM's response strategies consistent with improving the environmental performance of the supply chain?

Simulation results show that in a competitive, profit making business regime, responses that improve the environmental impact of the supply chain cannot improve the competitive position of the OEM vis a vis competition from remanufactured products. The analysis excludes competition from other supply chains. The paper discusses why it is not likely that supply chain actors will manage their operations towards a more sustainable closed loop configuration. The implication is that supply chain actors will remain locked-in in a mode of interaction that blocks the sociotechnical system from moving in a sustainability direction and hence contributes to system inertia. The supply chain will continue to operate primarily in a forward mode, supplying brand new products to the market.

The remainder of this article is organised as follows: Section 2 provides a background discussion on supply chains, Section 3 discusses competition in reverse supply chains, and Section 4 presents a qualitative model of the exemplary case in the paper. Next, in Section 5 a system dynamics model is developed while model results are presented and discussed in Section 6. Section 7 discusses why supply chain actors in a competitive business regime will likely remain in a lock-in situation rather than radically alter their trajectory. Section 8 concludes.

2. Firms in closed supply chains: an overview

In response to the increased internal sociotechnical pressures, such as stricter regulations and increased customer demand, companies need to develop their capabilities in assessing, managing