Dynamic development and execution of closed-loop supply chains: a natural resource-based view

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Abstract

Purpose

This research reflects on recent closed-loop supply chain (CLSC) practices using a natural resource-based (NRBV) and dynamic capabilities (DC) perspective.

Design/methodology/approach

Two empirical case studies of CLSC exemplars are used to discuss the theoretical relevance of these views.

Findings

Shows how strategic resources help companies in two sectors achieve successful CLSC designs. Strategic supply chain collaboration is an important success factor but also presents a number of challenges. The NRBV is used to explain the importance of new resources in technology, knowledge and relationships, and stresses the role of DCs to constantly address changes in the business environment to renew these strategic resources.

Research limitations/implications

This research elaborates on NRBV theory related to CLSCs and reinforces the inclusion of DCs. It specifies the application of NRBV in the context of textiles and carpet manufacture, and highlights the inherent conflicts in seeking value while moving toward sustainable development.

Practical implications

Investments in technical and operational resources are required to create CLSCs. Pure closed-loop applications are impractical, requiring relationships with multiple external partners to obtain supply and demand for recycled products.

Originality/value

Provides insights into the constituent resources needed for successful CLSCs. Helps move CLSC research from a tactical logistics problem to a problem of strategic resources and relational capabilities: what we term 'dynamic supply chain execution'. Our paper develops a framework for transitioning towards CLSCs, underlining the importance of co-development and forging new

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relationships through commitment to supply chain redesign, co-evolution with customers and suppliers, and control of supply chain activities.

Keywords: Natural Resource-based View, Dynamic Capabilities, Closed-loop Supply Chains

1. Introduction

The purpose of this paper is to use the Natural Resource-Based View (NRBV) as a lens to explore the dynamic capabilities (DCs) that lead to successful product stewardship in closed-loop supply chains (CLSC). CLSCs have been defined as "*the design, control, and operation of a system to maximize value creation over the entire life cycle of a product with dynamic recovery of value from different types and volumes of returns over time*" (Guide and Van Wassenhove, 2009, p10). This perspective is chosen in response to the need to take a more integrative approach to research on CLSCs including environmental and social goals (Govindan *et al*., 2015), the need to understand value creation as opposed to damage limitation (Krikke *et al*., 2013) and the importance of strategically relevant capabilities and partnerships in creating this value (Sarkis *et al*., 2011; Bell *et al*., 2013; Insanic and Gadde, 2014; Matopoulos *et al*., 2015).

Our investigation of two CLSCs, for carpet tiles and composite textiles, explores how capabilities develop over time and support the transition to a closed-loop model. The study focuses on two industry sectors where the lack of financial incentive and technical challenges pose significant barriers to firms redesigning their supply chains to follow a closed-loop approach, thereby filling an important gap in current knowledge (Simpson, 2010). In both sectors the value of returned products is relatively low compared to other sectors that have been studied extensively, such as PCs, automotive parts (González-Torre *et al*., 2010) and photocopiers, creating a value proposition challenge (Krikke *et al*., 2013). Furthermore, the technical barriers to recycling products that are bonded by complex adhesives and protected by chemical additives, which in turn are composites of PVC and polyester, require the development of new capabilities across the supply chain. Environmentally speaking, the materials content of these products are under the spotlight regarding their extensive damaging effects on the environment once disposed e.g. dangers of micro-plastics to sea life (Browne *et al*., 2013). Research to date has tended to focus on the consumer end of CLSCs and is still in its theoretical infancy (Simpson, 2010). This study is centered on B2B relationships, moving beyond the predominance of retailer-manufacturer research in CLSC, towards building a more complete picture of supply chain roles. We choose two exemplars in two sectors to provide evidence on how successful CLSCs can be explained through the lens of NRBV and DCs, and explore the challenges within these supply chains in developing and configuring their capabilities to fit a new business model.

To create the conditions for successful product stewardship using CLSCs, firms develop capabilities which span not only the supply chain, but also other stakeholders such as NGOs, institutions

and even competitors (Seitz and Peattie, 2004). Product stewardship is driven by the need for competitiveness through product differentiation through green raw materials and legitimacy by pre-empting and setting environmental standards. Yet traditional theories around core competence and RBV suggest a dilemma for firms seeking to explore collaborative links with other firms in the spirit of supporting sustainability, when they need to retain core knowledge which supports their unique selling point or market advantage (Esty and Porter, 1998). Hart's (1995) emphasis on dynamic external relationships and the need to share core knowledge presents a significant theoretical and practical challenge in rethinking the boundaries of firms seeking to transition to CLSCs.

Reviewing NRBV 15 years after Hart's original article, Hart and Dowell (2011) argue that the NRBV perspective remains relevant and offers further opportunity for empirical research. The NRBV places more emphasis on external resource access than traditional RBV, yet to date there have been few attempts to analyze how NRBV may help to better understand CLSC development and management (Sarkis *et al*., 2011). We argue that developments in CLSC design must go beyond technical optimization around product recycling (e.g. De Brito *et al*., 2005) and include third party stakeholder involvement that requires inter-firm knowledge sharing, process integration and societal legitimacy (Morana and Seuring, 2007). Although sustainable supply chain management (SSCM) research has used a number of different perspectives (Sarkis *et al*., 2011), NRBV contributions are rare, often applying more to the outcome measures of sustainability performance of leading corporations than the role of capabilities for the adoption of collaborative supply chain redesign (e.g. Grosvold *et al*., 2014; Schaltegger and Burritt, 2014). Exceptions include research into the impact of lean capabilities or internal sustainability practices on SSCM (Hajmohammad *et al*., 2013; Gualandris and Kalchschmidt, 2014). Furthermore, rapidly changing institutional environments and markets call for understanding the role of DCs in SSCM (Beske, 2012) and their extension to the NRBV debate (Hart and Dowell, 2011). Understanding DCs for CLSCs in extending, reconfiguring or modifying the resource base (Teece *et al.*, 1997), and spanning multiple supply chain members (Defee and Fugate, 2010), seems crucial to the elaboration of theory linking NRBV and CLSCM.

Our paper relies on two empirical cases of CLSCs to address these gaps by answering three key questions. First, how does the changing environment lead to new objectives for existing capabilities e.g. pollution prevention, and drive new capability acquisition and development? Second, as collaboration is key to the acquisition and development of these capabilities, how do relationships need to be managed to achieve CLSC success? Third, how do these capabilities enable CLSC development through supply chain redesign, co-evolution and control? The analysis of the cases is used to develop an initial conceptual framework linking the NRBV, CLSC and the role of DCs.

2.1 Natural resources and dynamic capabilities

Originally proposed by Wernerfeldt (1984) but with earlier origins (Penrose, 1959), the RBV shifted the focus from competitive advantage to *sustained* competitive advantage in order to incorporate a long-term view of strategy that emphasized both past and future positions. Traditional RBV specifies that difficult to copy resources are tacit and socially complex (Teece *et al.*, 1997) and must be specific to the firm and not widely shared or distributed amongst firms. In comparison, the NRBV focuses on *natural* (biophysical) resources and proposes a dynamic and interconnected view of resources (Hart, 1995), where resource transferability is no longer seen as problematic (Barney, 1991) but rather as an imperative. Hart's three interconnected strategies (pollution prevention, product stewardship and sustainable development) are combined with the internal-external boundary spanning aspects between concerns over firm competitive advantage and wider societal legitimacy. As Hart suggests: "*firms that adopt product stewardship strategies will evidence inclusion of external stakeholders in the product development and planning process*" (1995, p100).

The NRBV has been used as a lens in the related fields of sustainable operations, green SCM and SSCM, but not in the domain of CLSCM with the exception of one survey in the Spanish auto parts sector focusing on lack of internal resources as barriers (Gonzalez-Torre *et al*., 2010). Building on the use of NRBV in SCM, researchers have highlighted the interplay between internal and external capabilities for green SCM (Lee and Klassen, 2008), a focus on inter-organizational resources to stimulate supplier engagement (e.g. Foerstl *et al*., 2010) and the reinforcing effects of collaboration (Vachon and Klassen, 2008) and organizational learning (Carter, 2005). The review by Sarkis *et al*. (2011) highlights the need for further development of NRBV by focusing on the inter-organizational learning elements and definition of what is meant by competitively valuable resources in this context.

A key insight from Hart's (1995) paper is that the NRBV should incorporate DCs. DCs are defined as the ability to integrate, build and reconfigure internal and external processes to address rapidly changing environments (Teece *et al.*, 1997; Helfat and Peteraf, 2009) and can be seen as a way of using 'flexible resources'. There has been little research bringing DCs and environmental strategy together, including pollution prevention, product stewardship and sustainable development. Of the few, Aragon-Correa and Sharma (2003) state that a proactive environmental strategy is a dynamic capability with the following characteristics: specific, identifiable processes, socially complex, specific to the organization, path dependent, embedded, non-replicable and inimitable. DCs appear only recently in SSCM research suggesting a need for not only more agile and flexible working practices between firms, but also supply chain mechanisms for sharing and responding to potentially sensitive environmental information (Wong, 2013). Beske (2012) proposes a conceptual framework of DCs in SSCM, building on Defee and Fugate (2010), which comprises SC redesign, coevolution with partners and new control mechanisms for the triple bottom line. Another example of a DC explanation in SSCM suggests innovation in sustainability practices as a DC supporting SSCM objectives (Kalchschmidt and

Gualandris, 2014). While neither the NRBV nor the concept of DCs has been applied to the CLSC context, we suggest that the sparse application to SSCM deserves further elaboration.

2.2 Closed-loop supply chains

The majority of research linked to CLSCs relates to reverse logistics and product returns. The field started with definitional research (Carter and Ellram, 1998; Rogers and Tibben-Lemke, 2001), and then concentrated on mathematical optimization of remanufacturing (Savaskan *et al.*, 2004), product recovery (Fleischmann *et al.*, 2000, French and LaForge, 2006) and returns management (Savaskan and Van Wassenhove, 2006). Recent review papers have summarized much of this optimization research, covering a plethora of possible decision scenarios (Souza, 2013; Govindan *et al.*, 2015) yet functional or tactical perspectives have often limited the research scope away from wider supply chain issues (Guide *et al.*, 2003). Furthermore, the reviews reveal that the integration of green or sustainability issues into CLSC research is still lacking.

The focus of this study is on CLSCs as part of a natural resource based strategy. As such this research considers 'environmental' returns rather than commercial or marketing returns, that are brought back into the supply chain in order to reduce environmental impacts of disposal. Hart (1995) proposes that product stewardship is one component of a natural resource-based strategy that considers the internalization of environmental impacts. Product stewardship is proposed to lead to competitive pre-emption through green product development, yet also involves reputation building and legitimizing through external stakeholder validation. Managing life cycle impacts means integrating the supply chain and creating closed-loop solutions, but research is still needed on how to do this (Seuring, 2004). Hart's conceptualization of product stewardship focuses on product design and not creation of closed-loop processes, so research is also needed on tiers of the supply chain where products return back upstream, whether end product manufacturers or sub-tier suppliers depending on the nature of the product and the closed-loop strategy.

It is only recently that a more strategic, resource-based analysis of CLSCM has been developed by exploring the implications more generally for the triple bottom line (Defee *et al.*, 2009; Bell *et al.*, 2013). Defee *et al.*'s (2009) conceptual study summarizes the key challenges to CLSCM relating to acquisition of products, remanufacturing/recycling and development of secondary markets moving beyond tactical efficiency issues, towards a question of business models incorporating risk, cooperation and alignment. They propose that supply chain leadership may play an important role in developing a CLSC capability. Recent theory development has also taken a resource scarcity approach distinguishing internal operational and policy resources (Bell *et al.*, 2013) but there are still many gaps in both knowledge and practice (Simpson, 2010). Research has begun to focus on CLSCM as a part of broader CSR and SSCM initiatives, although there is still a need to examine how companies reconfigure their

resources and capabilities to address these new challenges from a supply chain perspective (Bell *et al.*, 2012; Beske, 2012).

2.3 Emerging new research questions for NRBV and CLSCM

From the preceding literature, we argue that further theory development is required based on real world applications of CLSCs and that an NRBV perspective is a useful lens. This section aims to develop some new research perspectives to explore these issues. Table 1 summarizes the main theoretical concepts which inform our analysis of CLSC based on previous NRBV and DC perspectives. These dimensions, we suggest, are required for adopting successful strategies towards CLSCM.

Insert Table 1 here

Table 1 Concepts linking NRBV and DCs to CLSCM

In order to understand the context of companies operating in the CLSC domain it is important to explain why companies choose to engage in the first place. While many studies have explored drivers for CLSCs focusing on legislation or product differentiation (Carter and Ellram, 1998; Seitz and Peattie, 2004), understanding the reasons for these actions is still required to fully appreciate the context. Recent studies propose that drivers such as regulations, market demands and potential competitive advantage, need to be present (Defee *et al.*, 2009; Shi *et al.*, 2012; Rahman and Subramanian, 2012) in order for companies to invest in designing out toxic elements from products and processes (Hart and Dowell, 2011; Matos and Hall, 2007). This range of drivers stimulates new objectives and a number of technological and knowledge-based requirements for CLSCs. Hence the changing (dynamic) nature of these drivers helps explain the extension of existing capabilities and development of new ones (Klassen, 2011). This leads to our first research question:

RQ 1 *What is the impact of changing drivers of SSCM on CLSC related capabilities?*

The second question relates to the NRBV focus on the role of external stakeholders in the development of closed-loop resources and capabilities, allowing socially complex interactions that are competitively valuable (Hart, 1995). According to Hart and Dowell's more recent review of product stewardship "*firms that approach life cycle issues as specialized, disconnected aspects of the product are less likely to develop successful product stewardship strategies*" (2011, p1469). Meeting new technological and knowledge requirements for CLSCs requires external coordination and the acquisition and development of resources such as take back facilities or re-manufacturing/recycling processes (Govindan, 2015), but research too often focuses on internal resource development (Defee *et al.*, 2009; Simpson, 2012). This reflects a broad need for CLSC research "*that stretches beyond a focal firm and examines interaction with external parties*" (Insanic and Gadde, 2014, p261). Capabilities in acquiring used products,

returning them to the supply chain, rely on cooperation with customers and the treatment of returned products may require investment by suppliers, leading to the question of how these capabilities are developed collaboratively with external partners.

Most research on external collaboration of CLSCs has been conceptual so far. Defee *et al.*, (2009) suggest that a CLSC orientation requires both a strategic emphasis on the whole supply chain, including upstream and downstream integration as well as managerial focus on risk sharing, cooperation and alignment with firms in the supply chain. Supporting this view, one study of end-of-life recovery for cars, vehicle tyres and photocopiers reveals that relational resources are important when relying on links to downstream customers and upstream third party processors of recovered products (Miemczyk, 2008). Bell *et al.*, (2012), who develop a model of CLSC strategy from a resource advantage perspective, explain the role of internal firm resources and natural resource scarcity. While their research focuses on the part played by natural resource scarcity in enabling market based advantage, the foundation for their model of resources and CLSCM relies on internal firm-level operational and policy resources aiming at complying with or influencing regulations. This exchange with policy makers is proposed to provide legitimacy to action, but can also be achieved by integrating NGOs in processes (Parmigiani *et al.*, 2011) or other experts (Seuring and Mueller, 2008). Thus, in order to elaborate on the role of external collaboration to respond to multiple drivers of CLSCM, the second question asks:

RQ 2 How is collaboration with external stakeholders managed to develop a successful CLSCs?

The third question relates to the potential dynamic nature of CLSC capabilities and their effect on supply chain design and control (Beske, 2012; Wong, 2013). We argue that markets and institutional environments are dynamic so that CLSCs need to react to changes in order to maintain legitimacy and at the same time create competitive advantage. As Klassen (2009, p3) comments: CLSC research must "*ensure that our business perspective recognizes a broad range of performance metrics and the dynamic nature of customer expectations and market opportunities*". Two contemporary perspectives help us to define more precisely the core elements of DCs in relation to change, supply chains and CLSC. First, Defee and Fugate (2010, p180) highlight the changing perspective from static, firm centric capabilities towards the *"need to continuously renew boundary spanning supply chain capabilities…facilitated by the presence of a supply chain orientation and a learning orientation found across multiple partners."* They emphasize the importance of knowledge accessing and co-evolving across partners, where the collective agility of the supply chain in a continuously evolving environment comprises competitive advantage. Beske (2012, p372) develops these ideas in relation to investment in DCs and implementation of SSCM practice *"improves the agility of the overall supply chain and can lead to higher performance against the three dimensions of sustainability".* Beske (2012) suggests DCs for SSCM include supply chain redesign, partner development, co-evolution and control of the triple

bottom line by integration of performance indicators. Second, this work is further developed in the context of the food industry where knowledge sharing and SC co-evolution are emphasized as important (Beske *et al.*, 2014). The ability to try out new sustainable supply chain solutions and learn from them may also support this dynamic capability that can support new closed-loop solutions (Gualandris and Kalchschmidt, 2015). Based on the above, we ask how these elements of DCs influence CLSCM:

RQ 3 *How are CLSC capabilities dynamically executed and reconfigured over time?*

3 Method

Case study research is a powerful tool in operations and supply chain research (Meredith, 1998; Handfield and Melnyk, 1998; Voss *et al.*, 2002). Case studies are particularly suitable when investigating complex inter-organizational phenomena, enabling data collection from multiple actors (Halinen and Törnroos, 2005) and complementary data sources (Eisenhardt, 1989). Building theory from case studies is a research strategy which creates constructs from empirical evidence where the central notion is to develop theory inductively (Eisenhardt, 1989; Eisenhardt and Graebner, 2007). The purpose of our case studies is more in line with Ketokivi and Choi's (2014) idea of theory elaboration than theory building *per se;* therefore our case studies are not guided by *a priori* propositions but by relatively open research questions. Recognizing the intrinsic nature of rich description in management research (Yin, 1994) we therefore use case studies to elaborate concepts from which to draw wider conclusions for business practice (Voss *et al.*, 2002; Stuart *et al.*, 2002).

Our research examines two cases of CLSCs comprising commercial carpets and composite textiles selected because of their advanced development of closed-loop manufacture and supply chain development. We chose to conduct two case studies to ensure sufficient depth and richness in each case and to be able to compare and thereby make better sense of the findings within each case. Thus we seek to generate rich insights into CLSC development and to draw conceptual lessons from this analysis (Halinen and Törnroos, 2005). We decided to conduct two in-depth case studies within similar industries to ensure consistency in context, thereby producing similar results (Eisenhardt and Graebner, 2007). Although each case study is defined not as a single company but as a CLSC, both of the cases are exemplars in the sense that they represent organizations and practices that are ahead of normal industry practice (Pagell and Wu, 2009). 'CarpetCo' has won several awards (including Golden Apple and BOV Trophy awards) in recognition of it being a front-runner and role model in the industry for its CLSC and adherence of cradle-to-cradle principles. 'ComptexCo' likewise has won an award for one of its sustainability projects, although not yet specifically for its CLSC model. Ensuring similar characteristics in the two cases was important in enabling meaningful case comparison.

The level of analysis of our study is the supply chain where the perceptions of focal manufacturers and suppliers were recorded independently. Data from focal companies and their suppliers and customers were collected based on interviews conducted with respondents in senior managerial positions who were involved in key strategic decisions over supply chain partner selection and relationship development (e.g. Managing Director, CEO). Interview data was supported by secondary material including life cycle assessment (LCA) documents, internal presentations and press releases (see Table 2). As part of the interviewing process we also sought to map the supply chains (Gardner and Cooper, 2003), to gain a visual understanding of the key actors involved and the connections and flows amongst these with a particular focus on those actors responsible for recycling and return processes. Given our research questions, we also sought to capture the knowledge flows as elements of the production and post-production process. Shown in Figures 1 and 2, these are not intended as comprehensive network maps (Provan *et al.*, 2007), but focused mainly on trying to create a visual understanding of how the (circular) process worked and the main actors involved in this process (e.g. Shapiro *et al.*, 1992; Barrat, 2004).

Our interview questions were derived from the literature review and summary in Table 1 and developed for use in an interview setting (Appendix 1). The semi-structured interview guide aimed at exploring competitively valuable resources that support natural environment objectives (Hart, 1995) and the potential role of DCs in the CLSC context (Beske, 2012). However, we should emphasize that due to our focus on theory elaboration we did not seek to develop tightly formulated interview questions around theoretical constructs, instead preferring relatively open-ended questions that allowed interviewees to discuss freely around broad themes. Hence our interviews were semi-structured, but very much open-ended, following Easterby-Smith *et al.*, (1991: 75): the interview protocol contained a loose structure of questions which, while developed from the literature, allowed other factors to emerge during the interviews and enable the researcher "*to begin to plot out the developing themes*".

Internal and external stakeholders were interviewed to generate multiple perspectives and as an aid to triangulation (Voss *et al.*, 2002). Typically lasting 60-90mins, the interviews gave interviewees a chance to talk openly about their company, the market in relation to the CLSC, and any specific resources that helped in their success (Meredith, 1998; Denzin and Lincoln, 2005). Interview formats sought to accommodate the role, position and expertise of the different respondent groups. All interviews were either conducted on location or by telephone, and initially included a site tour that built a picture of the working environment. Asking for permission to record the interviews, the majority were recorded before being transcribed (Silverman, 2013). The following section describes in more detail how the analysis was conducted.

Insert Table 2 here

Table 2 List of cases data and interviewees

Analysis method

The within-case analysis was carried out before the cross-case analysis commenced. Within-case analysis involved using role-ordered matrices and pattern matching to identify the similarities and differences in the perceptions of the interviewed supply chain actors (Miles and Huberman, 1994). Cross-case analysis made use of the same techniques, but focused on capturing similarities and differences between the two cases. Our method of analysis was an iterative process following other research in this domain (Pagell, 2004), whereby after conducting the cross-case analysis, the concepts behind NRBV and DCs in Table 1 were used to provide an initial coding scheme for the interviews and other sources of data (see Tables 3 and 4). Hence we did not apply an assessment framework derived from the theory to capture and measure data, but instead aimed to create a conceptual framework developed inductively from the case studies whilst taking into account the theoretical concepts in the categorization of codes (Pagell, 2004). Where one researcher took the lead on coding each case study, two researchers read the transcripts from both cases and discussed areas of uncertainty in order to compare coding allocation of the raw data and to ensure inter-rater reliability (Voss *et al.*, 2002). This comparison across cases by the researchers ensured consistency and helped find common or divergent themes. The research themes that emerged based on theory of NRBV and DCs in the context of SSCM were presented in a tabular format (see Table 5) and provided the basis for responding to the three research questions. As a way of ensuring validity of the findings, we returned draft case study reports to the two focal companies to obtain their feedback on our interpretations and conclusions (Stuart *et al.*, 2002).

4 Findings

4.1 Case 1 – Developing a closed-loop supply chain for composite textiles

This first case covers the supply chain of composite textiles, "*a real nightmare*" to recycle, manufactured by ComptexCo and recycled by TexLoop: a joint venture between ComptexCo and PvcCo in Italy to produce PVC and polyester for various sectors including hose pipes and textiles for garden chairs. ComptexCo is situated mid-way in the supply chain between the raw material producers of polyester and PVC and their customers who use the textiles. The case focuses on these two main companies but questions covered interactions with end customers, new material suppliers and a new customer of recycled products (Figure 1). Detailed case data are available in appendix 2 (including first level coding and illustrative quotes).

Insert Figure 1 here

Figure 1 Composite textile closed-loop supply chain

The context of the case relates to the need for ComptexCo to develop a value-seeking strategy to counter low cost suppliers with the need for a large supplier like PvcCo to improve its corporate image. This CLSC development required significant resource sharing and redesign of the existing supply chain processes. The joint venture (JV) is seen as a way to provide a unique service to end users that is difficult to copy. Therefore, the means and objectives are shared, but the motivations are subtly different. ComptexCo is seen as driving the value proposition due to its supply chain position, but this cannot be achieved without the technical expertise of and joint investment with PvcCo, who integrated this new process with an existing PVC recycling plant in Italy. Both parties are involved in finding new partners for end of life material supply and new users of recycled product and share the burden involved in this.

Regarding collaboration, knowledge and control, both companies worked together for many years to develop new technical and operational knowledge to solve problems. Although PvcCo is more focused on the technical process of recycling and less on the CLSC operational side (collection, transport and storage organized by ComptexCo, there is a continual exchange between engineers and operational staff across both companies on issues (e.g. quality) that arise. ComptexCo represents the CLSC to end users when proposing new solutions, but needs clear visibility e.g. through LCA of the whole process and so full disclosure is needed on the process and product attributes.

4.2 Case 2 – Developing a closed-loop supply chain for carpet tiles

The second case concerns manufacturer CarpetCo and the arrangements with supplier 'SupplyCo' to assist in the development of a new CLSC for carpet tile production (Figure 2). CarpetCo began as manufacturer producing woven carpets in Northern Europe for home and commercial purposes in 1930. Competition today for world market share in carpets is high and the focal firm's main rival already has a comprehensive sustainability strategy in place. In 2007, CarpetCo's chief executive decided to adopt 'cradle-to-cradle' manufacturing inspired by the work of a US consultancy firm: "*I realized I had to change the whole company*" (CEO, 2011). While assuming a leadership role in the transformation of its supply chain, CarpetCo had already established a working relationship involving substantial knowledge sharing with SupplyCo: a global leader in the field of polymer material recycling.

Insert Figure 2 here

Figure 2 Carpet tile closed-loop supply chain

Starting with its popular carpet tile product range, CarpetCo's aim was to remove all uncontrolled or environmentally unstable substances such as bitumen. Asking suppliers to declare the precise ingredients of their material was difficult because often firms simply did not know details and were reluctant to incriminate themselves. As part of the CLSC redesign, CarpetCo introduced a take back initiative to incentivize customers and carpet fitters to return old tiles to its headquarters for recycling

and to stop dumping in landfill (Figure 2). Although not all customers adopted the system because of additional costs, the collected carpet tiles were recycled, involving shredding, separating and cleansing of the fibers enabling them to be blended with new carpet yarn.

SupplyCo agreed to provide support by sharing essential specialist material information to CarpetCo throughout the transition process. Demand is very high for their recycled plastic-based material globally, where their core capability is "*reproducing a product exactly like the raw material*" (CEO/President, 2014). The firm specializes in selling regenerated product at high profit margins because of the high 50 per cent recycled content requirement, which is an imperative for western carpets markets such as the US. Sourcing post-consumer waste means finding stocks of material such as old fishing net from across the world and transporting it by container ship for processing at the plant in Italy. In terms of other firms getting involved: "*very few of them are serious about investing real money. So, everybody loves these processes...but when you try to involve them, they aren't ready*" (CEO/President, 2014 ibid). Because it is not possible to simply acquire the technology or knowledge needed to deliver closed-loop plastic material, "*everything has to be developed internally...for the first time*". Despite collaboration between CarpetCo and SupplyCo existing for over 10 years, tackling the joint challenges associated with product and supply chain redesign remains difficult. The supplier feels that it is far from an optimal outcome in recycling a high percentage of used carpets because of the cost and quality issues involved, both of which require more supply chain partners to engage with CLSCs. Detailed case data are available in appendix 3 incorporating direct quotes from interviews as illustrations and shows the different perceptions of why and how the two companies developed their closed-loop solution.

5 Towards a natural resource-based framework of CLSCs

Both cases of composite textiles and carpet tiles are examples of supply chains adapting into a new market where the traditional dominant logic of 'take, make and waste' is no longer valid. This section is divided into three subsections drawing on our within-case (Appendices 2 and 3) and cross-case analysis (Table 3). Each subsection returns to the research question and follows with a reflective discussion on how the analysis links with theory.

Insert Table 3 here

Table 3 Analysis of case comparison: main findings

5.1 The impacts of a changing environment and drivers

The business environment surrounding both cases demonstrates that both the markets and regulatory requirements are changing, with *"uncertain legislative changes…banning phthalates from PVC"* (SD, PvcCo) and products that *"won't sell in the US unless they have at least 30% post industrial waste"* (CO, SupplyCo). There is a need for the responses of these CLSCs to adapt to new market opportunities, rapidly moving from commodity type offerings to greater levels of value add, such as the addition of LCA services i.e. *"We…developed some personalized life cycle assessment calculators"* (CD, ComptexCo). Furthermore, the needs and values of end consumers is also changing: *"For some markets…we can detect a new movement of consumers which are linked to social and environmental values*" (MD, ComptexCo). So, companies that embed within the CLSC offer market-sensing activities to both sensitize their immediate customers and to scan for opportunities. One example of this is illustrated in the following quote: *"We started working with architects because they are the key decision makers for carpets in office buildings"* (CEO, CarpetCo).

In the composite textile supply chain the drive for change relates to the need to de-commoditize the product and search for value in their mature markets, primarily Europe and the USA. While there are some cost savings to be made, the lack of recycling infrastructure for these products led to a realization of opportunity especially for clients who shared the same value. Coupled with an uncertain legislative environment the key supplier saw this as an opportunity to redeploy and redevelop existing assets toward a closed-loop offer: "*In addition to preserving raw material resources [*the process*] avoids incineration of post-consumer PVC waste*" (LCA, ComptexCo).

The carpet tile business was driven by the same realization that markets were evolving, creating new opportunities for product differentiation. This proactive approach was especially influenced by the company leadership who had become convinced that the cradle to cradle approach could allow them to respond to new markets and that this was the only option to allow long-term sustainability of the business: *"I realized I had to change the whole company"* (CEO, CarpetCo). On the supplier side,

similar explanations surfaced regarding opportunities for future business, such as: *"sustainability is the business of the future"* (VP, SupplyCo). Also, the ability to respond to uncertain legal changes in key markets limited the use of certain materials.

Our question: *"What is the impact of changing drivers of SSCM on CLSC related capabilities?"* is used to link these findings to NRBV theory. As discussed above, the changing drivers lead to the need to adapt and build on pre-existing capabilities as well as to create new ones to meet new technology and knowledge requirements. Ensuring toxic materials are removed and that the environmental case is made through LCA are important precursors, acting as hygiene factors or qualifiers, but only reinforce an already defined strategic intent. The cases show that the CLSC builds on pre-existing capabilities shown to support PP such as a proactive approach and innovativeness (Hart and Dowell, 2011). However, pollution prevention is *partly* out of the control of the main actors in a CLSC that accepts other sources of material into the recycling process, as reflected in this quote by CO in SupplyCo: "*There is real difficulty over fishing net collection, recycling, production and fibre extrusion*." While both manufacturers can minimize toxic content through product design, both recycling processes require other inputs to maintain volume (e.g. fishing nets and truck tarpaulins). This means the upstream recycling processes have to react on a continuous basis to varying quality of inputs, and also to actively seek inputs which meet quality and environmental criteria: "*Every product today has an LCA and we activate the calculation depending on what is the target or the goal*" (CD, ComptexCo).

In summary, the analysis suggests that there is a link explicitly between pollution prevention and product stewardship, even though the cases do suggest a move from cost reduction strategies to market pre-emption and differentiation. To an extent this dependency relies on the context (perceived value from customers) and the precise nature of the product and process (quality of inputs). From analyzing both cases, CLSCs would ideally rely only on the controlled inputs from the manufacturers and their customers where their product redesigns would help avoid many of the difficulties and to build fully on product-process capabilities. In reality, a pure closed-loop is impractical when the lack of scale creates many additional complexities and challenges that rely on collaboration with many external partners with varying objectives.

5.2 Collaborative development and planning

This part of the analysis focuses on the evidence from the cases that illustrate how required new resources (i.e. technological, knowledge) stem from relationships and the conditions under which these collaborations allow new resources to emerge.

The composite textile case is characterized perhaps foremost by the joint venture between the manufacturer and its key supplier of PVC which resulted in the development of new, unique recycling technology being developed which can chemically separate PVC from polyester fibres: *"We designed the plant from scratch with ComptexCo and developed it through a joint venture"* (SD, PvcCo), "*..this*

is the only process that can extract PVC from [composite textiles]" (MD, ComptexCo). The long-term development of technology and related know-how make the process hard to replicate, requiring economies of learning. For example, PvcCo attempted to license the rPVC process in Japan, and implementation failure was blamed on the need to climb a very steep learning curve. The conditions for this collaboration are based on sharing patents, licensing and revenues in an equitable manner: *"It's a very long story that started in 1997, the first patents, we are co-inventor with (PvcCo) of the process" (MD ComptexCo)*. This key relationship led to a major financial investment in new recycling technology, and while the manufacturer worked with clients and others to set up collection points, the level of technological development and knowledge for product acquisition appears less challenging. Although this existing relationship provides a unique technological asset, the other relationships also form essential elements of the new closed-looped system. The recycling process accepts waste from competitors, *"We recycle…the products of competitors"* (MD, PvcCo), but also offcut waste from 're-users' of composite textiles such as recycled bag producers, which came from a complaint that ComptexCo was using their source of supply, stating: "*It's a nightmare for us because we need them for our bags*" (MD ComptexCo). Customized client services based on tailored LCAs is an important part of the offer. These work because the manufacturer offers exclusivity of using the CLSC outcomes. Also, working with a loose network of partners (including recycling competitors) is important to retrieve composite textiles to achieve scale economies: *"The collecting network is through our fabricator customers, that's the collecting network for [*the product's*] plant"* (MD, ComptexCo).

Similarly, the carpet tile case indicates long-term commitments to develop new recycling technologies both at the manufacturer and the key suppliers, for example: *"We've been working with CarpetCo for 20 years"* (VP, SupplyCo). Yet despite long-term developments, the ownership of process knowledge is considered highly protected within each company: *"Our technology is very special…difficult to realize in the production of high quality product from post-consumer waste* (VP, SupplyCo). While many in the existing supply base have followed CarpetCo's lead in developing a CLSC, not all suppliers have been able to make the same commitments: "*Very few [*suppliers*] are serious in investing real money in these processes* (VP, SupplyCo). On the client side, new relationships have developed to demonstrate the value proposition to end users especially in the design phase so that dealing with architects has become more prevalent. The conditions for collaborative development of this CLSC are based upon long-term commitments, the ability to share information while protecting proprietary knowledge, and sometimes trimming the supply base to fit with new objectives: *"Ultimately, we have to threaten to remove them from our preferred suppliers list…we get the information, or we get another supplier"* (DoS, CarpetCo).

Understanding the planning and development phase is addressed theoretically by asking *"How is collaboration with external stakeholders managed to develop a successful CLSCs?"* In accordance with Table 5, the CLSCM planning phase requires the acquisition, sharing and development of

resources through partner interactions. Although resources existed in the firms before the CLSC strategy development it is the re-combination, acquisition and development of new physical assets, knowledge and relationships that allow the new strategy to be realized. There is no question that without significant collaboration and often joint investments with external partners, these supply chains would not exist. Significant commitment is required therefore, particularly to the upstream and relationship mechanisms that allow joint objectives to be met without compromising internal resources. There are numerous mechanisms for ensuring joint objectives are reached, for example the granting of access rights to customers, joint asset investment and shared technology licensing. However, each has to be tailored to the appropriate inter-organizational collaboration and requires significant time to develop. In both cases, these are complex social interactions at multiple levels occurring over many years: *"We have to keep on nagging…we cannot force [*suppliers*], the only thing we can do is persuade [*them*] that cradle-to-cradle makes business sense"* (DoS, CarpetCo).

There was also evidence that knowledge is developed and shared at multiple levels with multiple actors during the development of these two CLSCs. This knowledge is used to create new processes to collect and recycle materials and to develop products in which to use them. The constant challenge to balance quality requirements with environmental objectives creates a need to find new technical solutions and new partners to buy end of life products and to sell the results of these new processes: *"We are in B2B: we have one hand on the final market [*and*] we have one hand on the supplying market"* (MD, ComptexCo). Not only is technical expertise needed, but also knowledge of how these recycled products can be used in divergent markets (e.g. garden chairs, hoses, insulation, construction) can impact viability. In some cases this can happen almost by chance, such as the example of ComptexCo finding a new customer for recycled polyester. Despite a willingness to share their knowledge 'for the greater good', these supply chains may be difficult to replicate in other contexts. New partners can be brought in, but under the condition they comply with the 'rules' set up by the existing collaborations. For example, new customers for rPVC are incentivized with exclusive rights to use the recycling system, but then have to commit to using the take back system. Conflicts of sharing knowledge with suppliers have to be resolved through negotiation, and some suppliers, often the bigger brands, resist taking part: *"The big chemical raw producers from fossil fuels are not helping"* (CO, SupplyCo).

A rather surprising finding however is that there was no evidence of a significant role of NGOs in the development of these CLSCs, neither to provide expertise nor to legitimize strategies. This suggests success is not dependent on actively seeking external legitimacy from NGOs, but rather on using sound science, at least for these cases.

5.3 Dynamic supply chain execution

The first section demonstrated that both cases of CLSCs were subject to dynamism in the business environment in terms of changing market requirements and social norms. This section provides an overview of how the supply chains respond to these dynamics in order to achieve economic and environmental sustainability objectives.

The textile supply chain is characterized by continuous adaptation of processes both on the recycling technology side and the material recovery side of the supply chain, for instance: *"We are learning and changing the process all the time" (CM, PvcCo).* The various challenges related to varying input quality and quantity requires process adaptation, where CLSC partners have to search for resources to cope with these changes in variation either internally, or as is often the case, externally: *"We have a co-operation with [*another recycling company which makes bags by reusing composite textiles*],*" (CEO, ComptexCo). The original value offering based on tailored life cycle assessment required considerable upskilling in LCA using external consultants. Other internal supply chain exchanges (e.g. engineers) also allow a focus on continuous improvement of economic and environmental performance and new partners are frequently brought in as part of this continuous development: *"We have done all this work with a 'consultant'…you have to amortize the impacts over one or two cycles* (CM, PvcCo). A lack of labour resource and need for increased quality control led to a new relationship with a charity with experience in sorting textiles to *"share the sorting of products"* (CEO, ComptexCo). Development with new clients to use recycled PVC also meant the sharing of new product and process knowledge between the JV partners and a garden hose producer. On the supply chain control side, there is no formal link to SAP for example, and many of the processes towards the product collection side are more informal. The LCAs are independently verified and the heavily regulated recycling process highly automated in terms of process control and this could be seen as way to build legitimacy.

At the beginning of the carpet tile CLSC development consultants were used to access new knowledge specifically on the formal and technical element of the cradle to cradle approach. In the carpet tile CLSC, the configuration of a new retrieval system is seen as key and becoming more demanded by end users in their building renovations, for instance: *"Some customers say they only want to buy from manufacturers who can 'take back'"* (DoS, CarpetCo). However, this means continuously convincing and educating fitting contractors to apply the retrieval process. Once materials are recovered the challenge is to provide non-landfill solutions to untreatable wastes in the new CLSC, which requires new relationships with other industries that might find a use for these by-products e.g. construction materials: *"We try to build an international community using the cradle-to-cradle system"* (CEO, CarpetCo). Again, to achieve scale, other sources of plastics feed into the supplier processes and the challenge is to manage these inputs regarding quality and quantity often from 'non-industrialized' sectors, such as the fishing industry. Overall, a focus on short-term objectives is not effective because the main partners at least need reassurances that their investments will be worthwhile in the longer term:

"The whole process requires a little more effort from the supply chain…It's a very fine line: everybody is looking for the cheapest way to get rid of material" (DoS, CarpetCo). These elements together appear to be supported by environmental leadership, especially by CarpetCo.

Change over time and ability to adapt is addressed by asking *"How are CLSC capabilities dynamically executed and reconfigured over time?"* While this research has not taken a longitudinal perspective, the data does provide a historical view of the development of these supply chains. In both cases there is a constant search for new market opportunities. Here we can distinguish between different types of supply chain capabilities and link them specifically to recent conceptualizations of DCs in the context of sustainable supply chains (Hart and Dowell, 2011; Beske, 2012; Kalchschmidt and Gualandris, 2014). These are summarized in Table 5 under what we term dynamic supply chain execution.

The capability to develop new supply chain processes, such as a new recycling plant, requires co-development and investment in a particular technology. The physical asset itself can be seen as rigidity, for example if legal requirements change, ending the use of PVC or other compounds. Yet as both the manufacturer and supplier are affected by this, their developed capability in sharing product and process knowledge and developing new relationships endures, and can be applied to other technological options: "*We are learning and changing the process all the time, with the new centrifuge and finding new supply sources, this has been a 13-year development project*" (CM, PvcCo). Hence, this can be seen as a dynamic and collaborative capability, which corresponds to the idea of co-evolution in the supply chain (Defee and Fugate, 2010, Beske, 2012), but also reflects the 'innovative' character of these companies to try new things (Kalchschmidt and Gualandris, 2014). In fact, this ability to co-evolve is embodied in the leadership of these CLSCs supporting other work on CLSC orientation (Defee *et al.*, 2009). We question whether this dynamic cycle can be maintained in the absence of such supply chain leadership. A further element of this dynamism is that while resources and capabilities are shared between partners, the loss of commitment from one partner can quickly put the strategy in danger of being accused of green-washing, for example: *"They [*the manufacturer*]…try to minimize their financial exposure to these types of activities, but when they communicate with the market it's different!"* (VP, SupplyCo). Thus, it seems that it is the leadership and dynamic capability of only one of the partners, essentially the one with reach to both the market and supply resources, which allows continued success through the search for new partners.

Accessing new knowledge and bringing in new partners are inextricably linked in these cases: "*it's important to build cooperation between people who are different, different business, different way of thinking, different market, the more we are different the best we can cooperate*" (CD, ComptexCo). The point of departure in both cases relies on new life cycle knowledge being developed with consultants, acting both as experts and knowledge brokers to provide the 'sound science' behind both CLSCs. Making a life cycle-based value proposition to end clients is a new development in these

markets which requires convincing and educating end users and external parties. While NGOs played no developmental roles in our cases, the threat of negative reputational communication from pressure groups ensures that the CLSC partners protect their end customers' interests. Constantly varying quantity and quality of inputs requires finding new supply and demand sources for recyclable/recycled products. To achieve this the CLSC partners are searching and then developing new processes with producers of waste (e.g. the French farming community as users of tarpaulins) to collect and control quality of waste, and new users of recycled product to use recovered bitumen (e.g. construction industry) or polyester (e.g. textile weaving industry): "*We are learning and changing the process all the time, with the new centrifuge and finding new supply sources,*" (CM, PvcCo**).** This requires scanning abilities, but then development of new relationships and processes to achieve shared objectives, for example where a completely new user of recycled polyester was found in the CompTex case "*we tried to do some yarns with these fibres and it is really possible with the last company in France…they are the last ones to do that…we found them almost by chance*" (MD, PvcCo). Derived from our case studies and reflecting on extant literature, Figure 3 provides an initial conceptual framework, which incorporates the factors involved in the transition towards CLSCs. The framework emphasizes the significance of what we term dynamic supply chain execution and collaborative internal/external firm development, which are supported by drivers and antecedents, and ultimately leading to CLSCs through co-development between partners and commitment to relationships. The framework indicates that the core actors – not only a focal firm - in the CLSC initiative would need to put these factors in place for success.

Insert Figure 3 here

Figure 3 An initial conceptual framework for transitioning towards CLSCs

The last element of DCs that may pertain to CLSCs and is also reflected in our framework in Figure 3 relates to control of the supply chain to achieve the various objectives, especially those related to economic and environmental sustainability. Beske (2012) views this as a sophisticated accounting system constantly checking performance against objectives. Neither case exemplified a 'sophisticated' supply chain control system, for example due to difficulties integrating supply chain information systems with environmental performance indicators, where: *"We have SAP, it is not linked to the LCA system…too many problems to resolve in the LCA evaluation and method*" (MD ComptexCo). Both cases apply externally verified life-cycle assessment procedures with their partners that provide a common supply chain level of knowledge which can be shared from raw material supply to end users. However, bringing in many new partners who are not traditionally part of the supply chain, does not necessarily fit with high levels of formal control and requires a more flexible approach. Hence the most

important ‘control’ may be the long-term commitment and shared values of the partners to achieve a financially and environmentally sustainable CLSC.

6 Conclusions and contributions

Our research builds on the resurgence of interest in reverse logistics as part of the new innovation economy, linking NRBV theory with firm strategy and CLSCs. It extends thinking on the role of boundary spanning and DCs and responds to the need for further empirical studies on CLSCs and natural resources (Defee *et al.*, 2009, Sampson, 2010, Matopoulos *et al.*, 2015). Hart (1995) and Hart and Dowell (2011) argue that strategies concerning pollution, stewardship and sustainability are embedded and overlapping with a path dependency that begins with a low cost focus on minimization of emissions, effluents and waste. To progress towards product life cycle costs and address the overall environmental burden of growth and development, greater awareness within firms is required of the interconnectedness between lower costs, pre-emption of competitors and consideration of what future position the firm and its partners is seeking to achieve through sustainable development.

6.1 Theoretical contributions

Although research on CLSCs is well developed, little research to date has sought to analyze the development of CLSCs through an NRBV lens and even fewer studies have examined this topic through in-depth case studies. Using the NRBV perspective has enabled us to capture how companies, which have actually developed CLSCs, tackle the complex challenges of developing CLSCs. Bringing together the established theory of NRBV and CLSC, we have elaborated on both NRBV and current articulations of DCs to show that some conditions are less important, while others require greater emphasis (thus respecting Ketokivi and Choi’s (2014) duality criterion of case research). Here we wish to highlight five theoretical contributions.

First, our research confirms that product stewardship is driven by the need for lower life cycle costs and market reorientation, rather than only reacting to legislative requirements, which may be the case for other sustainable supply chain actions (Shi *et al.*, 2012). Both cases confirm that CLSCs can provide competitive advantage through securing access to ‘green’ raw materials, by setting standards (i.e. being pre-emptive), and generating positive reputation and legitimacy. We incorporate these elements together in our understanding of what defines successful product stewardship. These drivers lead to investment in new resources related to technology and knowledge to meet new CLSC objectives, which build upon previous ‘internal’ capabilities (environmental proactivity or leadership and innovation) linked to pollution prevention (Hart and Dowell, 2011). However, our findings suggest that these are insufficient hence the need to develop relational capabilities and invest in significant

collaborative efforts to support a complete re-design of the supply system (Govindan *et al.*, 2015; Bell *et al.*, 2013; Miemczyk, 2008; Barratt, 2004).

Second, our study suggests that pollution prevention capability supports product stewardship, building on innovation and environmental leadership, on external stakeholder engagement (although not necessarily NGOs) and internal and external integration skills (Parmigiani and Klassen, 2011). In fact, our study provides little evidence that pollution prevention, in the form of product redesign, is essential. Our case study examples would not be viable as pure CLSCs, using only the focal manufacturer's products, but had to include input from 'outside' actors (e.g. fishing nets and tarpaulins) in order to maintain scale economies. We thus elaborate NRBV theory (Hart and Dowell, 2011), arguing that pollution prevention capabilities, including an innovation orientation (Gualandris and Kalchschmidt, 2015), are needed before embarking on CLSCM, but some issues are out of the firm's control leading to end-of-pipe controls (e.g. sorting, testing).

Third, the case analysis suggests that innovation and leadership capabilities are extended, beyond the PP focus and take on a whole supply chain level role. Innovation in the form of new processes and technologies are co-developed with partners and shared through specific relationship conditions, what we term 'co-evolution with customers and suppliers'. Thus, internal innovation experience is leveraged between key partners to obtain shared solutions such as in the recycling joint venture in one of our cases. In parallel, environmental leadership (proactivity) is also extended beyond internal PP efforts to lead supply chain level initiatives. In this sense, supply chain leadership (Defee, 2009) is supported by environmental proactivity (Aragon-Correa and Sharma, 2003), which alone is insufficient to achieve CLSC objectives. This '*sustainable supply chain leadership*', supports supply chain level initiatives as well as co-evolution and control and may be seen as a relational capability (Gualandris *et al*., 2015).

Fourth, both cases indicate that high-level collaborations were needed between core partners, typically manufacturers and suppliers (Defee and Fugate, 2010). Simply outsourcing to recycling specialists is not an option (Simpson, 2010). The logistical challenge was relatively trivial compared to the technical ability to recycle and re-use recycled materials in new products and to ensure long-term economic viability. Our research supports the need for long-term commitment between core partners based on agreed mechanisms to share benefits and to jointly develop the process and network over time. Our study also shows that new relationships were needed to achieve economic, quality and environmental objectives with third parties not normally associated with these supply chains. In our cases the development and exchange of knowledge on products and process was essential for success. However, not all supply chain actors wanted or even needed to be involved: some suppliers in our cases simply refused to engage and perhaps surprisingly NGO inclusivity was low, acting only as observers (Gualandris *et al*., 2015). Instead, consultants (or knowledge brokers) were used to develop scientific evidence to support legitimacy claims. Here, the role of life cycle analysis in product stewardship shows

that capability is important in managing interdependencies, where LCA knowledge is integrated not only across functions (Matos and Hall, 2007) but also across firms and is becoming a defining element of the value offer.

Fifth, our work supports the views of Hart and Dowell (2011) that the NRBV in the CLSC context could be further elaborated to incorporate DCs related to supply chains. Despite the challenges with boundary spanning, managers need to look beyond the totality of their organization when considering product stewardship and pollution prevention together as part of strategic sustainable supply chain development. This further highlights the role of supply chain level leadership (Defee *et al.*, 2009). This research shows the inherent challenge in simultaneously achieving competitive advantage through value seeking capabilities and the imperative of sustainable development. In both cases the strategic resources of technology, knowledge and relationships are socially complex, path dependent, and are regularly renewed to cope with business environment dynamics through accessing knowledge and resources and co-evolving the supply chain (Defee and Fugate, 2010; Beske, 2012). Viewing the outcomes of these CLSCs as product and process innovations (Gualandris and Kalchschmidt, 2015), facilitated by 'sustainable supply chain leadership' perhaps indicates that a number of DCs need to be developed to achieve successful CLSCs in general.

6.2 Managerial implications

Both of our examples of CLSCs required investment in time and financial resources over significant timescales. Alongside this, the actors were required to share risks not only financially but also operationally due to uncertainties of demand and supply. In one of the cases the logistical issues were seen as relatively trivial, and so simply holding many month of end-of-life material supply was the main strategy to deal with these uncertainties. In these sectors where the value of returned product per ton is relatively low, such a buffering strategy may be appropriate.

CLSC in its pure form is an ideal state, so in reality systems have to be 'partially closed-loop' in order to obtain sufficient supply of end-of-life products and find sufficient market in which to sell the recycling products. However, this creates a challenge of input variability both in terms of volume and quality: dealing with the diversity of end-of-life product is a real challenge from a practical point of view and while both of our cases experimented with multiple means of sorting, manual methods may produce the best results with current technology. This is not necessarily in conflict with the objectives of a 'sustainable' CLSC. Social enterprises and charities have been involved with reselling products (e.g. furniture, books, PCs) for a number of years. As shown in the composite textile case this could lead to new opportunities for collaboration in the so-called 'circular economy' whereby the need for employment is filled by new CLSC processes, and perhaps this is an indication for where product stewardship leads to sustainable development. A life cycle approach would be needed to ensure impacts

were not increased by offshoring the sorting process to developing countries, but perhaps advances in social LCAs could help make informed decisions.

Finally, scaling up these CLSCs to societal levels is not easy, and many companies simply do not have the commitment or capability. Therefore, a societal-level solution would have to make these resources readily available to all (i.e. through government subsidy) and ensure that the business environment is stabilized by better organizing supply and demand of recyclable/recycled products and minimizing legal changes.

6.3 Limitations and further research

Our study relies empirically on two in-depth case studies, which is clearly limited in terms of generalization to other firms and to other sectors. However, it is difficult to find cases of CLSC and to access not only single but multiple firms across the supply chain willing to reveal the difficulties associated with CLSC redesign. In fact, our cases show that the supply chains resemble networks rather than chains, further complicating research on these phenomena in terms of boundary definition and access to data. Each of our cases relies mainly on detailed information from two key supply chain players supplemented by secondary data and ancillary interviews with consultants to corroborate evidence at the supply chain level, but is inevitably incomplete. Our findings suggest that much of the challenge revolved around the level of required investment in collaboration being so high. We also found limited NGO collaboration in our cases, but we would advise caution in empirically generalizing from this result. The findings raise further questions around partnership risk and opportunism, which we think warrant further research either through a transaction cost approach or, adopting a longer-term perspective, a relational perspective (Dyer and Singh, 1998).

Although the differences in the timing of our interviews (i.e. by several years) did not reveal obvious differences in our analysis, we do acknowledge the potential limitation that stems from having conducted the two cases retrospectively and at slightly different points in time, especially when exploring past decisions. In seeking to retain the comparative element between our chosen cases, we justify our selection on the basis of our *'common study objectives and themes…using the same theoretical base* [and maintaining] *interaction between group members by meetings* (Halinen and Törnroos, 2005: 1294). In other words, the development of our interview protocol helped to accommodate issues around differences in network boundary, complexity and the time dimension by offering a loose structure of common questions on which to build the investigation. We tried to address any further gaps in our understanding of the cases by using techniques such as follow-up interviews.

In general, more empirical research is needed to understand what works and why. CLSC research is still an area under considerable development, trailing advances in knowledge of new product and service development. The idea of the circular economy is gaining more and more traction, especially from the public arena, but also with social enterprises that are emerging with new solutions and business

models. Further research could focus on other institutional contexts such as Eastern Europe, North America and Asia. Research could also focus on the role of knowledge in supply networks to provide new solutions in a collaborative environment, focusing on different classifications of knowledge (Kogut and Zander, 1992). Understanding the limits of knowledge co-development and sharing may open such studies to use coopetition thinking to help explain future practice.

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Appendices 1-3 available on request from the authors

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Tables and Figures

Table 1 Concepts linking NRBV & DCs to CLSCM

Theoretical view	*Potential implications for CLSCs*	*References*
NRBV implications for CLSCs		
Drivers of CLSCM	• Legislation, customers, new markets, competitive advantage (through differentiation)	Carter and Ellram, 1998 Kumar and Malgeant, 2006 Defee *et al.*, 2009; Rahman, and Subramanian, 2012 Gualandris and Kalchschmidt, 2015
Factors enabling and resources supporting CLSCM	• Physical Assets (take back facilities, etc.) • Knowledge and learning processes (markets, processes) • Relationships (suppliers, customers, regulators, NGOs) • Operational and policy resources	Govindan, 2015; Souza, 2013 Bell *et al.*, 2013; Defee *et al.*, 2009 ; Hart, 1995, 2011 Shi, 2012; Sampson, 2010; Miemczyk, 2008; Foerstl *et al.*, 2010; Bell *et al.*, 2013 Defee *et al.*, 2009
Path dependency and learning from pollution prevention	• Strategy complementarity: pollution prevention, product stewardship and sustainable development • Previous toxics removal, LCA approach • Development, learning, innovation and experience over time	Hart, 1995, 2011 Hart and Dowell, 2011 Aragon-Correa and Sharma, 2003

Resource acquisition, sharing and development	• Highly coordinated activities involving large numbers of people and teams, few people grasp the overall phenomenon	Hart, 1995, 2010; Aragon-Correa and Sharma, 2003
Development of capabilities with partners (economic and non-economic)	• Building legitimacy (with NGOs) • Using external technical capabilities • External stakeholders involved in the (eco-) NPD process; understanding business interdependencies in LCA approach • Joint ventures and co-development • Role of supply chain leadership	Parmigiani *et al.*, 2011 Seuring and Mueller, 2008 Kumar and Malgeant, 2006; Lee and Klassen, 2009; Vachon and Klassen, 2008 Miemczyk, 2008 Defee *et al.*, 2009
DC implications for CLSC		
DCs for Agile SC DCs for SSCM Innovation orientation	• Redesign of the supply chain; accessing new knowledge • Co-evolution with partners; • Supply chain control, use of information tools, transparency • New actors (customers, suppliers); stakeholder inclusion • Proactive environmental strategy (environmental leadership) • Trying new ideas and solutions; willingness to try new processes	Defee and Fugate *et al.*, 2010 Beske, 2012; Beske *et al.*, 2014 Beske, 2012; Wong, 2013 Hart and Dowell, 2011 Aragon-Correa and Sharma, 2003 Kalchschmidt and Gualandris, 2014

Table 2 List of cases data and interviewees

Cases	*Companies*	*Interviewees*	*Date / location*
Composite Textiles	ComptexCo, Central France • *Employees:* 630 • *Turnover:* 143 million Euro PvcCo, Italy • *Employees:* 1500 • *Turnover:* 1.2 billion Euro	• Managing Director (MD) • Chief Executive Officer • Commercial Director (CD) • Managing Director (MD) • Site Director (SD) • Compliance Manager (CM)	May 2014 May 2014 May 2014 June 2014 June 2014 June 2014
Carpet Tiles	CarpetCo, Netherlands • *Employees:* 1000 • *Turnover:* 202 million Euro SupplyCo, Italy • *Employees:* 2150 *Turnover:* 472 million Euro	• Chief Executive Officer (CEO) • Director of Sustainability (DS) • Chief Commercial Officer (CCO) • Vice President (VP) • Communications Officer (CO) • Vice President (VP)	Sept 2011 Sept 2011 Sept 2011 Nov 2011 Mar 2014 Mar 2014
Secondary data	*Secondary interviews:* LCA provider / Consultants Managing Director Technical Director & foreman.	*Documents:* LCA documents Internal presentations Marketing & press releases	*Site visits:* ComptexCo, France PvcCo, Italy CarpetCo, Netherlands

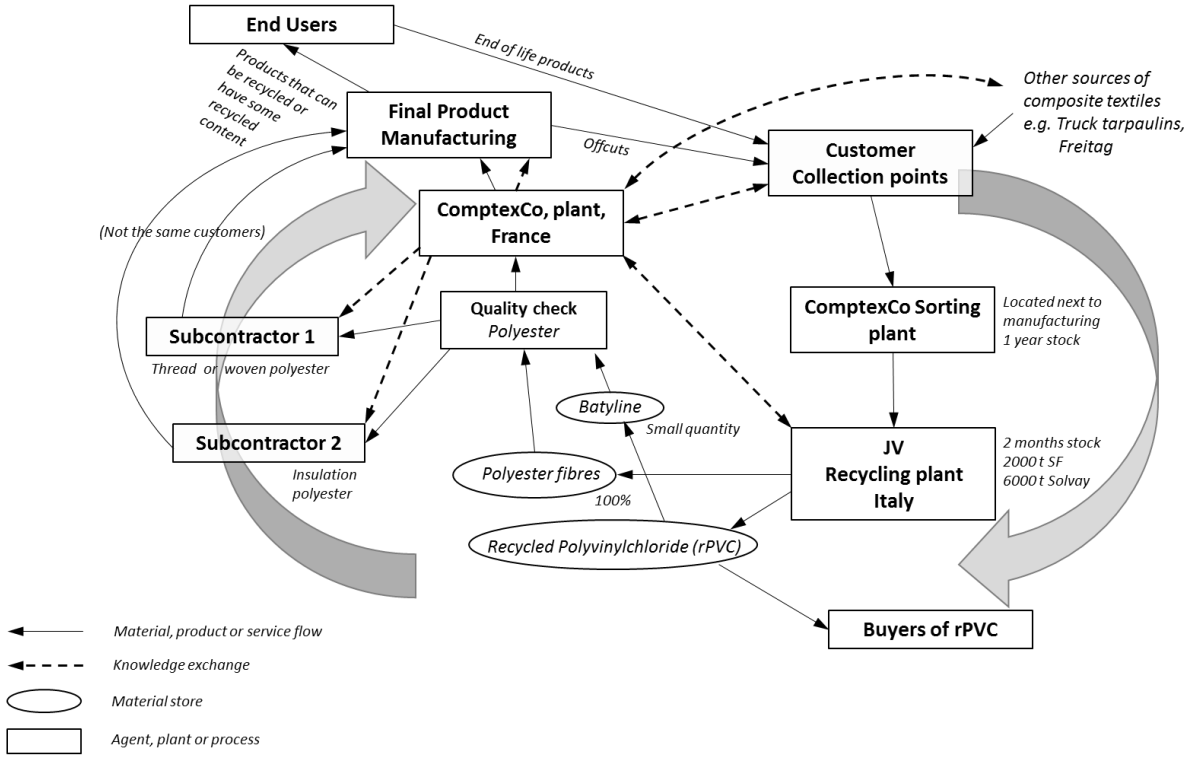

Figure 1 Composite textile closed-loop supply chain

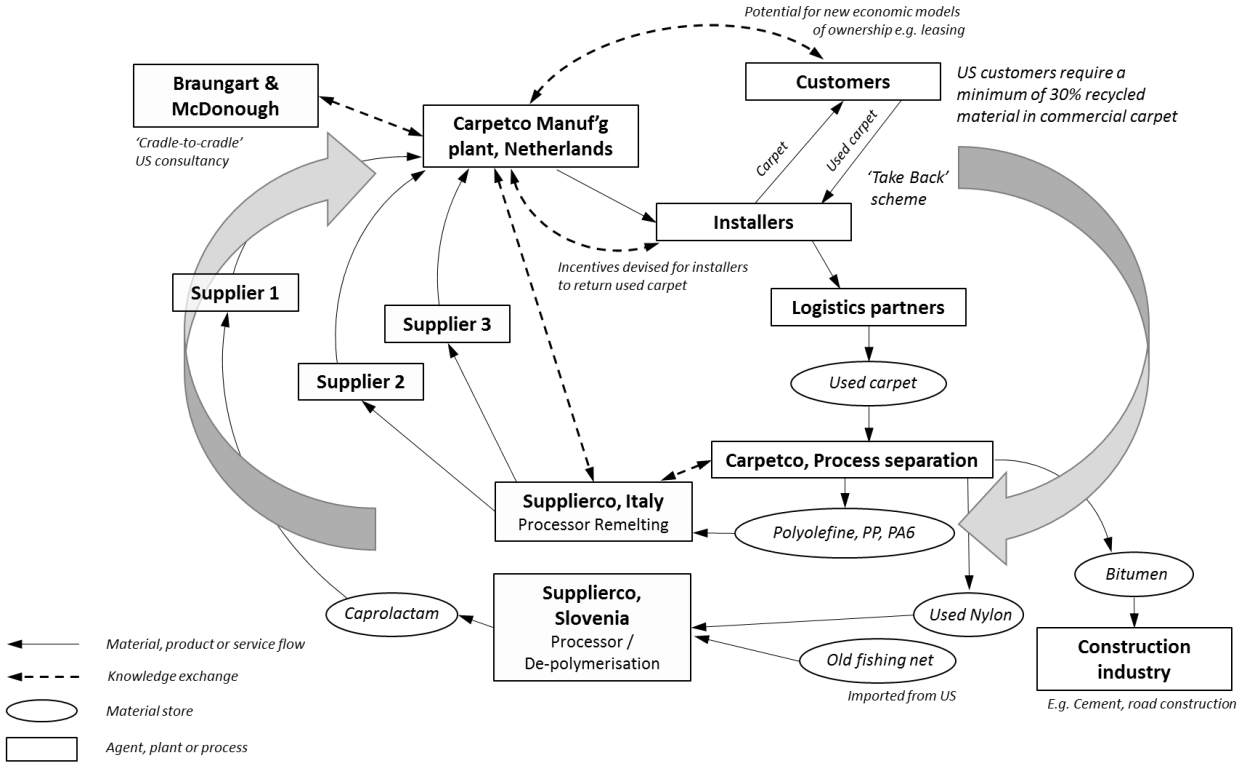

Figure 2 Carpet tile closed-loop supply chain

Table 3 Analysis of case comparison: main findings

Concepts	Carpet tiles	Composite textiles
RQ1 What is the impact of changing drivers of SSCM on CLSC related capabilities?		
Drivers and business environment characteristics	• Growing demand for raw material with recycled content • US carpet market demands a min. recycled quota of 30% • Specialist suppliers demand premium price for raw material	• New/growing markets – responsible consumers • Uncertain legal changes
New requirements		
Building on pre-existing capabilities, path dependency & learning	• Manufacturer initially interested in "proactive" ecology based projects • CEO decides to adopt C2C (life cycle view) • Supplier independently developed PS & PP in tandem, inspired by waste from the city	• Move from cost reduction / commodity focus to a value focus working with end user 'innovative' applications • Has ISO14001, but not used to support the CLSC strategy • PS not dependent on product redesign, but builds on 'green' strategy and proactivity
Technology requirements	• Production Engineering and product technology held by manufacturer • Carpet yarn, nylon material ingredients and new reprocessing technology held by supplier	• Unique PVC/ polyester textile recycling technology (co-developed by manufacturer and supplier) • Low cost sorting processes (manual)
Knowledge requirements	• To operate a carpet take-back system, firm needs to know ingredients of <u>all</u> product types • Sourcing post-consumer waste requires extensive knowledge of overseas supply market	• Recycling process know-how that is socially complex and difficult to copy • Technical legitimacy of LCA, open & independently verified • Customized LCA for end users • New sources of supply & demand
RQ2 How is collaboration with external stakeholders managed to develop a successful CLSCs?		
Relationship requirements	• Sharing of material ingredients important but via a third party is acceptable • Must allow capabilities around specific USP to still be owned by individual firms	• Customized CLSC solutions for end users with exclusivity • Expanded vertical, strategic supplier relationship (joint venture) • Horizontal 'flexible' collaboration with competitors and 'external networks' to obtain scale
Collaboration conditions	• Initial material price agreement supported by commitment to long-term collaboration • Major role played in development by supplier • Development process often conducted between client, OEM & supplier • Focus on sustained and collective effort by all	• Value focus, not low cost • Share licensing, patents & revenue between manufacturer and supplier • Supply chain position – influence up and down stream • Integration into supplier production system (economies of scale and learning) • Long term commitments • Not directly competing clients
RQ3 How are CLSC capabilities dynamically executed and reconfigured over time?		
Redesign & reconfigure the supply chain resource base	• Manufacturer accepts any used carpet tiles in take-back system • Continuous improvement of recycling process with supplier • Finding new uses for by-products of un-recyclable material	• Created recycler JV with supplier – unique asset • Continuously adapt processes and supply sources with supplier • Co-develop collection points with clients • Finding new material customers

Bring in new actors	• C2C consultants inspire vision • Third party data sharing site • Supplier extends sphere of influence into the US market for new sources of waste material	• Social enterprises (supply sources) • Charities (labour) • Consultants (LCA) • Suppliers (recycling processes)
Accessing new knowledge	• Closer relations with customers reveals service requirement levels for product retrieval • *New market knowledge included in product design with suppliers*	• Develop new LCA knowledge with consultants • Engineering knowhow exchange • New recycling byproduct use • Educate customers on solutions
Control supply chain activities	• Independent C2C consultants offer independent material quality control rating • Recognition that information of common interest (i.e. material ingredients) must be shared	• Informal flexible controls on CLSC logistics and partners through commitment • Formal controls on recycling process constantly adapted to changing rules • Independently verified LCAs • LCA separate from SAP as not flexible

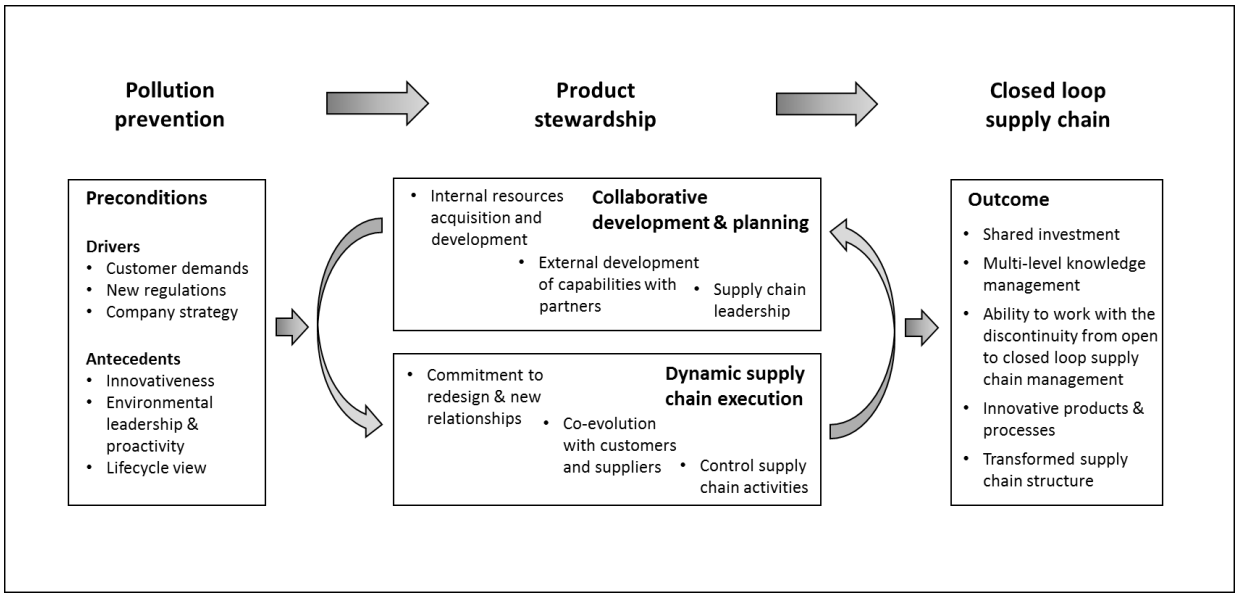

Figure 3 An initial conceptual framework for transitioning towards

Appendices

Appendix 1 – Interview Guide

1. Please describe your business environment characteristics related to the product stewardship / closed-loop supply chain activities[**].

[**] Hints/keywords: Markets – transparent, volatile, international, Products – success based on changing technologies and combinations of companies and stakeholders, Performance – not just financial measures required

2. Please describe how knowledge, technologies and other assets[††] are important for successful product stewardship, how effective you are in using them compared to your competitors, please give examples? ***The rest of this interview refers to these resources***.

3. To what extent are you involved in **redesign** of the supply chain related to closing the loop, bringing in new actors, stakeholders and other supply chain companies?

4. How have you as an organization evolved to create new, synergistic combinations of resources and also **co-evolved** with you customers and your suppliers:
    a. *Is your firm's approach to pollution prevention, product stewardship and sustainable development connected, in terms of each strategy complementing the other?*
    b. *Is each strategy or approach (as above) path dependent on or linked to another?*
    c. *Please explain whether your firm's strategy/approach has involved the progression from a lower cost strategy (i.e. minimize waste), to pre-emption of competitors and a future position on overall sustainable development?*
    d. *Have your internal resources developed over time through repeated learning and experience in the firm?*

5. What is your involvement in the **development** of capabilities on both your customer and supplier side – so that their performance improves the supply chain performance overall?

6. How important is acquisition, sharing and development of **knowledge (and/or other resources)** internally and externally to help the closed-loop supply chain development
    a. *How do you share or transfer a resource with another firm in the supply chain even when considered a source of sustainable competitive advantage?*
    b. *What are the conditions for sharing resources between firms?*
    c. *Does resource development require highly coordinated activities involving large numbers of people and teams?*
    d. *To what extent do only a very few people grasp the overall closed-loop process in your firm?*

7. How does the following help **control** supply chain activities: use of information tools (records, updates, environment scanning, etc.) and their alignment to KPIs and goals at the supply chain level to meet the overall objectives of closed-loop/product stewardship?

Appendix 2 - Summary findings from composite textile case (including indicative verbatim quotes)

	ComptexCo	PvcCo
RQ1 What is the impact of changing drivers of SSCM on CLSC related capabilities?		
Context and environment Uncertain and dynamic environment	**Lack of recycling opportunities for some end products** "*Because I receive 50 tons per year from an activity which was not able to pay for recycling, so they have the added value, so it's like a kind of symbiosis cooperation and natural one*" **MD**	**Uncertain legislative changes on material contents** "*Uncertain legislative changes for example banning phlalates from PVC so we're looking to stop some inputs*" **SD**

[††] Material content of products, toxicity, new and future rules and regulations, new recycling techniques, information systems that allow you to share internally and external, relationships, location of your plants to suppliers and customers and so on.

	Some cost savings but minimal "*In addition to preserving raw material resources (the process) avoids incineration of post-consumer PVC waste*" **Independent verified LCA**	
New resource requirements / Path dependency • Technology • Knowledge • Relationships	**New & unique textile recycling technology and process know-how** "*We have invented with [PvcCo[a physical process based on different dilution in a solvent*" **MD** **Customer exclusive life cycle solution** "*We will sell you the rPVC at a normal price, we will do all the environmental evaluation , …. you will be the only one in Europe who will have an access to the impact figures of the rPVC for this application*" **CD** **Customized lifecycle assessment for end customers** "*We have also developed some personalized lifecycle assessment calculators …. not a general calculation*" **CD** **New collection relationships developed with textile customers** "*The collecting network is through our fabricator customers, that's the collecting network for TexLoop plant*" **MD**	**New & unique textile recycling technology and process know-how** "*We designed the plant from scratch with Ferrari and developed it through a joint venture*" **SD** **Within JV process know-how which is difficult to copy** "*Original patents of SF are more than 20 years old….. nobody has copied us because as we design and build our own equipment*" **MD** **Technical legitimacy, independently verified** "*The GWP of the (recycling process) is 40% lower than the benchmark*" **Independently verified LCA report** **Horizontal collaboration with competitors to achieve scale** *"We recycle also the products of competitors*" **MD**
RQ2 How is collaboration with external stakeholders managed to develop a successful CLSCs?		
Collaboration conditions for obtaining new SC resources • Positive and negative	**Suppliers need to focus on value not low cost commodities** "[Suppliers] *feel in western Europe there is nothing to do, the future is Eastern Europe and Asia*" **CEO** **Position in supply chain allows synergies between client & supplier** "*We are in B2B we have one hand on the final market we have one hand on the supplying market we can be the key player* " **MD** **Integrate into existing production system to leverage scale and learning** "*The reality is different its more complicated it's a very big plant with two processes the [process a] one and [process b] one*" MD **More scale further back in supply chain** "[Customers] *they cannot build a plant and use a plant, that's the only way, but they don't try to do it because it's very expensive*!" CEO	**Split licensing and patents with customer (in JV)** "*We are co-inventor with Ferrari of the process, we have the patent by they have an exclusive license of using the patents and all the improvements of the patents on all the world for my family of products because* **MD** **Revenue sharing agreements in JV** "*Input its 8000 tons per year and we have a capacity of 2000 for [*the buyer*] and they use only 1000 tons …we share the revenue 30/70*" **MD** **Long term commitment with customer** "*It's a very long story that started in 1997, the first Patents*" **SD**
RQ3 How are CLSC capabilities dynamically executed and reconfigured over time?		
Adaptation and continuous change of SC	**Bring in new actors such as social enterprises and charities** "*[A charity] which is specialized in collecting clothes….we. share the sorting of my products and they will do it a part in their facilities*" MD	**Continuously adapting recycling process and supply sources** "*We are learning and changing he process all the time, with the new centrifuge and finding new supply sources, this has been a 13 year development project*" **CM**

• Develop and redesign/reconfigure CLSC (extend/modify resource base) • Bringing in new actors /span SC • Accessing new knowledge • Control of changing CLSC	"*We have a cooperation with (*other recycling company*), which is a different approach to the circular economy*". CEO **Engineers exchange knowhow on environmental improvements** "*The plant is in (Italy) it's not in France but (*our engineers*) go sometimes, … they try to reduce water & energy consumption of the machines*" MD **LCA not linked to SC control systems (SAP)** *"We have SAP , it is not linked to the LCA system…… too many problems to resolve in the LCA evaluation and method*" **MD** **Adapts LCA output to changing objectives** "*Every product today has an LCA and we activate the calculation depending on what is the target or the goal*" **CD**	**Help new end customers use recycled product in their processes** "*With PVC granulates we set up a new business experience with (customer), big convertors of PVC which produces garden ..*" **MD** **New LCA knowledge brought I with consultant help** *"We have done all this work with 'consultant'… you have to amortize the impacts over one or two cycles*" **CM** **New yarn production process with traditional weaving company** "We tried to do some yarns with these fibres and it is really possible with the last company in France …they are the last ones to do that" **MD** **Compliance (safety & environment) constantly updated** "*Highly regulated with the plant being Sevesa and we have to consider REACH (the first in Italy), RoHS and we have ISO14001 so we have one person dedicated to tracking regulation and compliance issues*" **CM**

Appendix 3 - Summary findings from composite textile case (including indicative verbatim quotes)

	CarpetCo	***SupplyCo***
RQ1 What is the impact of changing drivers of SSCM on CLSC related capabilities?		
Context and environment Uncertain and dynamic environment	**Realization by management of the market demand for sustainable products** *"I got acquainted with Cradle-to-cradle. I realized I had to change the whole company"* CEO **Growing links between sustainability and the future of the business** *"It started with [*CEO*], this thinking about sustainability. Because if we are not sustainable how can we do business in the future?"* Director of Sustainability (DoS) *"By 2020 I want all our products to be C2C"* CEO	**Strong association by supplier between sustainability and future business** "*If you want to survive you must follow this. Sustainability is the business of the future*" Vice-President (VP) **US legislation on recycled material content driving the global supply market** *"Commercial carpets won't sell in the US unless they have at least 30% post-industrial waste included."* Communications Officer (CO) *"Our market is global for our closed-loop type product*" VP
New resource requirements /Path dependency • Knowledge • Technology • Relationships	**High levels of investment and path dependent learning needed** *"We have four strategies [but] the most important is innovation and C2C*" CEO *"[CarpetCo's] yarn cycling process has taken 2 years to develop"* DoS **Investment by partners is required to develop new toxin-free processes** *"The 'seven carcinogen' supplier says he can design the product without"* DoS **Knowledge of consultants & NGOs help to influence senior management**	**Suppliers consider recycling process technology as a major competitive advantage** "*Our technology is very special…difficult to realize in the production of high quality product from post-consumer waste."* VP **Need to find new & reliable sources of recyclable material which may be outside of the current supply system** *"There are difficulties in the purification of the material but also in finding good sources of [waste] raw material which is recyclable"* CO **Long-term involvement of key suppliers needed to develop closed-loop processes**

	"*I saw a DVD from [a consultant] and I was so impressed by the documentary, I said this is what we need to do"* CEO *"CarpetCo and [competitor] both started down this route around the same time. Heavily influenced by Ray Anderson's book"* DoS **Closer relations required with key customers & clients** *"We started working with architects because they are the key decision makers for carpets in office buildings"* CEO	"*We have been working with [CarpetCo] for 20 years"* VP **Knowledge of new legislation required & control over specific chemicals** *"Working with a large company made life much easier. [They were] under strict controls: chemical substances will soon be forbidden in the EU."* VP
RQ2 How is collaboration with external stakeholders managed to develop a successful CLSCs?		
Collaboration conditions for obtaining new SC resources • Positive and negative	**Increase in information sharing seen as vital by the manufacturer** "*This is the tricky part: we are pushing our suppliers to provide us with information."* DoS **Suppliers may not share data because of perceived threat to the business** *"Suppliers are very reluctant to give data because fears of customers going to another supplier with their USP"* DoS *"Half of them said: why should we give you totally non-toxic materials?"* CEO **Tactics are sometimes needed to persuade SC partners to participate** *"Ultimately we have to threaten to remove them from our preferred suppliers list…we get the information, or we get another supplier"* **DoS** *"We have to keep on nagging. We cannot force [*suppliers*], the only thing we can is persuade [*them*] that C2C makes business sense."* **DoS**	**Limited motivation from some other suppliers to invest or participate** "*Very few [other* suppliers*] are serious in investing real money in these processes…when you try to involve them they aren't ready to participate."* VP **Evidence of short-termism by some suppliers & vested interests in using non-renewable resources** *"The big chemical raw producers from fossil fuels are not helping" CO* *"The customer side is not easy to find real cooperation because they [only] see short-term problems"* CO **Suppliers want more recognition for their capability in recycling & processing** "*We are able to reproduce exactly product like the virgin raw material. Our marketing policy is to sell it as 'regenerated' product…recycled at 50 per cent"* VP *They [*manufacturer*]…try to minimize their financial exposure to these types of activities but when they communicate with the market it's different!"* VP
RQ3 How are CLSC capabilities dynamically executed and reconfigured over time?		
Adaptation and continuous change of SC • Develop and redesign/reconfigure CLSC (extend/modify resource base) • Bringing in new actors /span SC • Accessing new knowledge • Control of changing CLSC	**Offering product retrieval is now regarded as key service requirement by world markets** *"Some customers say they only want to buy from manufacturers who can 'take back'* DoS *"Urban mining is the way to go: in China they understand that"* CEO **Sharing information on ingredients is seen as essential by manufacturer** *"Information sharing is an issue… sometimes second tier suppliers do not want to talk to [us]" DoS* **Introducing new partners as an independent control and means of rating material quality** "*We try to build an international community using the Cradle-to-cradle system through [consultants] "* CEO *We have a third tier supplier who doesn't want to talk to anybody but EPEA"* DoS	**Information is shared between OEM and supplier in areas of common interest** *"We exchanged a lot of information with [manufacturer]: a natural match"* VP **Issues must be resolved of working with partners who supply used material outside of the EU** *"There is real difficulty over fishing net collection, recycling, production and fibre extrusion"* CO **Some waste material is incinerated and then sold to suppliers in other industries e.g. house building & highway construction** "We are currently disposing of untreatable waste in a way that doesn't involve landfill" CO **CLSCs require a sustained collective effort from all SC partners** "*When they [*customers*] discover this type of project or initiative, the money looks nice. But you don't make money quickly so they are discouraged" VP*

	CLSCs require a sustained collective effort from all SC partners *The whole process requires a little more effort from the supply chain…It's a very fine line: everybody is looking for the cheapest way to get rid of material."* DoS	