



Sustainable supply chain management and the transition towards a circular economy: Evidence and some applications[☆]



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ABSTRACT

In the last decades, green and sustainable supply chain management practices have been developed, trying to integrate environmental concerns into organisations by reducing unintended negative consequences on the environment of production and consumption processes. In parallel to this, the circular economy discourse has been propagated in the industrial ecology literature and practice. Circular economy pushes the frontiers of environmental sustainability by emphasising the idea of transforming products in such a way that there are workable relationships between ecological systems and economic growth. Therefore, circular economy is not just concerned with the reduction of the use of the environment as a sink for residuals but rather with the creation of self-sustaining production systems in which materials are used over and over again.

Through two case studies from different process industries (chemical and food), this paper compares the performances of traditional and circular production systems across a range of indicators. Direct, indirect and total lifecycle emissions, waste recovered, virgin resources use, as well as carbon maps (which provide a holistic visibility of the entire supply chain) are presented. The paper asserts that an integration of circular economy principles within sustainable supply chain management can provide clear advantages from an environmental point view. Emerging supply chain management challenges and market dynamics are also highlighted and discussed.

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1. Introduction

Circular economy [49] represents a theoretical concept which aims at creating an industrial system that is restorative by intention [75,69]; in recent times, business have become more aware about such a concept, seeing it as a mechanism that can be used to create competitive advantage [25]. As such, the paper seeks to address the implications of these practices in a supply chain context from environmental, market, policy and societal points of view.

The recent embracing of new business models that encourage design for re-use and improve materials recovery represents a departure from historic production and consumption systems. In fact, classical economic theory posits that disproportionate production and consumption patterns represent a natural or desirable outcome since they drive the creation of wealth resulting from economic activity (including the flow and use of raw materials and resources) and trade of goods and services [73]. However, it has also been established that economic and production systems cannot be separated from the

environment, with contemporary ecological economic theory emphasising the increasing impacts of human activities on the natural environment [16,40]. This phenomenon has led to the crossing of certain biophysical thresholds [63]. As a result, the emphasis on sustainability, a concept which is now integrated in most disciplines since the publication of the Brundtland Report by the World Commission on Environment and Development [13], has become even more important in the present time.

The increasing influence of sustainability in supply chain management and operations practices can also be attributed to the fact that, in addition to increased demands of strong economic performance, organizations are now held responsible for the environmental and social performance by major stakeholders [92,86]. As such, sustainability has forced the redefinition of the operations function [19]. Additionally, sustainable supply chain management has become a strategic process enabling firms to create competitive advantage [72]. This assertion is backed by Porter's [58] hypothesis, which states that the conflict between environmental sustainability and economic competitiveness is a false dichotomy based on a narrow view of the sources of prosperity and a static view of competition.

Within this context, in the last decades, sustainable supply chain management theories have been emerging (*inter alia*: [87,69,66]). These frameworks are underpinned primarily by product lifecycle

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influences and operational influences [65]. Savaskan et al. [67] suggest that the requirement to take a holistic view of the whole product supply chain is a fundamental step for establishing greener and more sustainable production systems [35], based on re-using and re-manufacturing materials [94]. These systems could also lead to the creation of new competitive business models [42]. Such models could be based on the paradigm of *cradle-to-cradle*, encouraging the use of raw materials known as technical and biological nutrients, which do not have a negative impact on the environment, have an entirely beneficial impact upon ecological systems and return to the ecosystem without treatments [12].

Interestingly, the concepts of green and sustainable supply chain management have been developed in parallel (although there are some fundamental differences in principles) to the circular economy discourse, which has been propagated in the industrial ecology literature and practice for a long time [46,24]. In fact, sustainable supply chain management seeks to integrate environmental concerns into organisations by minimizing materials' flows or by reducing unintended negative consequences of production and consumption processes [75,76,66,21]. On the other hand, as described by McDonough et al. [50], circular economy pushes the frontiers of environmental sustainability by emphasising the idea of transforming products in such a way that there are workable relationships between ecological systems and economic growth [31]. This is achieved by creating a paradigm shift in the redesign of material flows based on long-term economic growth and innovation [12]. It is implied that circular economy is not just concerned with the reduction of the use of the environment as a sink for residuals [8] or with the delay of cradle-to-grave material flows (as sustainable supply chain management suggests) but rather with the creation of metabolisms that allow for methods of production that are self-sustaining, true to nature and in which materials are used over and over again [49].

Finding ways to align sustainable supply chain strategies to circular economy principles has therefore become important if the boundaries of environmental sustainability are to be pushed. Additionally, circular economy is primarily concerned with material flows in economic systems [54,47] through a paradigm shift in production philosophy; this therefore leaves other important issues such as understanding environmental impacts (such as the ones related to energy usage and carbon emissions) and the implications of such impacts unresolved. Consequently, the main research questions which would be addressed in this paper are:

- How can sustainable supply chain management be enhanced by aligning it to the circular economy concept?
- What are the environmental implications of circular production systems in terms of carbon emissions, resource use and waste recovered when compared to a traditional linear production paradigm?
- What are the potential market dynamics, policy and societal implications that could arise by the implementation of circular production systems? What kind of challenges do they pose?

In order to answer to these questions, based on the theoretical constructs of circular economy, two case studies (based on product supply chains from different process industries) are analysed. The findings would be used to provide insight to the analysis and discussions. Chosen case studies are concerned with food (specifically, the waste cooking oil supply chain) and chemical (ferrous sulphate supply chain) industries. Greenhouse gas emissions (in the following, simply referred to as *carbon emissions*) were selected as the main environmental impact indicator because of their prominence in contemporary literature and as a result of easy access to data.

Food and chemical supply chains were chosen for this study because (apart from the fact that they are two very different process industries) both supply chains have been known to have significant consequences on the environment. Additionally,

according to Beamon [10] limited research has been carried out on the food processing sector mainly because of the complexity of the supply chain, hence leaving important issues involving waste, re-use of resources, greenhouse gas (GHG) emissions unaddressed [32]. Regarding the chemical industry supply chain, OECD [55] reports that despite it being one of the most regulated of all industries, there is a potential for a negative impact at every stage of its lifecycle. This situation is exacerbated by the increased use of chemicals in major economic development sectors [82].

To address these issues, the paper is structured as follows: in Section 2, a literature review is conducted on the principles of circular economy, on frameworks for evaluating the environmental performance of supply chains and on supply chain configurations. In Section 3, methodological notes and generalities about the case studies are presented. Section 4 addresses the key findings, analysis and discussions of the study leading to the concluding remarks reported in Section 5.

2. Theoretical backgrounds

2.1. The circular economy paradigm

Environmental economics is concerned with identifying and solving problems related to damage and pollution associated with the flow of residuals [30,8]. In this context, the principles underlining circular economy suggest that, by assuming the planet as a closed system, the amount of resources depleted in a period is equal to the amount of waste generated in the same period. This principle is thus subject to the Laws of Thermodynamics [84,62], although in practice this is not the case because Daly [18] reiterates that the circular flow of exchange (which consist of the physical flow of matter and energy) is ultimately linear and unidirectional beginning with low entropy resources from the environment and ending with the pollution of the environment with high entropy waste. Despite these limitations, due to basic physical laws, the paradigm of circular economy seeks to continually sustain the circulation of resources and energy within a closed system (the planet) thus reducing the need for new raw material inputs into production systems. The principles of circular economy thus reveal an idealistic ambition of pushing the boundary of sustainable supply chain management practices. Such practices, indeed, are ultimately concerned with the reduction (or the delay) of unintended negative impacts on the environment due to cradle-to-grave material flow [59]. Thanks to initiatives such as The Circular Economy 100 [25], a number of companies have embraced these concepts also as a mechanism for collective problem solving. The circular economy paradigm has then provided a framework by means of which businesses operating within the same supply network (and beyond) can engage with sustainability activities, enabling best practices to be adopted.

In this context the concept of *Reverse Supply Chain Management* has been developed [32,44] as an adaptation of circular economy principles to supply chain management. Indeed, a reverse supply chain includes activities dealing with product design, operations and end-of-life management in order to maximize value creation over the entire lifecycle through value recovery of after-use products either by the original product manufacturer or by a third party.

Reverse supply chains are either *open-loop* or *closed-loop*. Basically, open-loop supply chains involve materials recovered by parties other than the original producers who are capable of reusing these materials or products. On the other hand, closed-loop supply chains deal with the practice of taking back products from customers and returning them to the original manufacturer for the recovery of added value by reusing the whole product or part of it [32]. Because of the benefits of reverse supply chains, it is unsurprising that manufacturing industries have been placing, recently, a lot more emphasis on achieving

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