



A review on circular economy: the expected transition to a balanced interplay of environmental and economic systems



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ARTICLE INFO

Article history:

Received 3 September 2014

Received in revised form

26 August 2015

Accepted 1 September 2015

Available online 16 September 2015

Keywords:

Circular economy

Resource efficiency

Reuse

Recycling

Zero waste

Sustainability

ABSTRACT

In the last few years Circular Economy (CE) is receiving increasing attention worldwide as a way to overcome the current production and consumption model based on continuous growth and increasing resource throughput. By promoting the adoption of closing-the-loop production patterns within an economic system CE aims to increase the efficiency of resource use, with special focus on urban and industrial waste, to achieve a better balance and harmony between economy, environment and society. This study provides an extensive review of the literature of last two decades, with the purpose of grasping the main CE features and perspectives: origins, basic principles, advantages and disadvantages, modelling and implementation of CE at the different levels (micro, meso and macro) worldwide.

Results evidence that CE origins are mainly rooted in ecological and environmental economics and industrial ecology. In China CE is promoted as a top-down national political objective while in other areas and countries as European Union, Japan and USA it is a tool to design bottom-up environmental and waste management policies. The ultimate goal of promoting CE is the decoupling of environmental pressure from economic growth. The implementation of CE worldwide still seems in the early stages, mainly focused on recycle rather than reuse. Important results have been achieved in some activity sectors (e.g. in waste management, where large waste recycling rates are achieved in selected developed countries). CE implies the adoption of cleaner production patterns at company level, an increase of producers and consumers responsibility and awareness, the use of renewable technologies and materials (wherever possible) as well as the adoption of suitable, clear and stable policies and tools. The lesson learned from successful experiences is that the transition towards CE comes from the involvement of all actors of the society and their capacity to link and create suitable collaboration and exchange patterns. Success stories also point out the need for an economic return on investment, in order to provide suitable motivation to companies and investors. In summary, the CE transition has just started. Moreover, the interdisciplinary framework underpinning CE offers good prospects for gradual improvement of the present production and consumption models, no longer adequate because of their environmental load and social inequity, a clear indicator of resource use inefficiency.

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1. Introduction

Over the last decade growing attention has been paid worldwide to the new concept and development model of Circular Economy, CE, with the aim to provide a better alternative to the

dominant economic development model, so called “take, make and dispose” (Ness, 2008). The negative effects caused by the latter are threatening the stability of the economies and the integrity of natural ecosystems that are essential for humanity's survival. (EC, 2014a,b; Lett, 2014; Mazzantini, 2014; Park and Chertow, 2014; Su et al. 2013; Geng et al., 2012; UNEP, 2013a; Waughray, 2013; Ellen Macarthur Foundation, 2012; Preston, 2012; Stiehl and Hirth, 2012; Feng and Yan, 2007; Yuan et al., 2006; Yap, 2005).

So far many different CE studies (case studies, reviews, scientific reports, etc.) have been published worldwide (Yap, 2005; Andersen,

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2007; Feng and Yan, 2007; Charonis, 2012; Ellen Mac Arthur Foundation, 2012; Preston, 2012; Su et al., 2013; Lett, 2014; Naustdalslid, 2014; Prendeville et al., 2014; Club of Rome, 2015; Resource, 2015). A large number of these studies concern the implementation of CE in China. This country seems strongly committed and attracted by CE because of the huge environmental, human health and social problems posed by its very rapid and continuous economic development pattern (Yap, 2005; Fang et al., 2007; Feng and Yan, 2007; Geng and Doberstein, 2008; Geng et al., 2012; Mathews and Tan, 2011; Mazzantini, 2013; Su et al., 2013; UNEP, 2013a). Circular economy is seen as a new business model expected to lead to a more sustainable development and a harmonious society (Feng and Yan, 2007; Geng and Doberstein, 2008; Ness, 2008; Mathews and Tan, 2011; Europesworld, 2014; Lett, 2014; Naustdalslid, 2014). Sustainable development requires balanced and simultaneous consideration of the economic, environmental, technological and social aspects of an investigated economy, sector, or individual industrial process as well as of the interaction among all these aspects (FAO, 2002; Ren et al., 2013). Circular economy contributes positively to reconcile all the elements, thanks to its underlying rationale, mainly rooted in environmental and political (Birat, 2015) as well as economic and business aspects (Ellen Macarthur Foundation, 2012). CE promotes a more appropriate and environmentally sound use of resources aimed at the implementation of a greener economy, characterized by a new business model and innovative employment opportunities (Ellen Mac Arthur Foundation, 2012; Stahel, 2014), as well as by improved wellbeing and evident impacts on equity within and among generations in terms of both resource use and access: “A world in which poverty is endemic will always be prone to ecological and other catastrophes” (World Commission on Environment and Development, 1987).

CE has most often been considered only as an approach to more appropriate waste management. Such very limited point of view may lead CE to fail, in that some recycling, reuse or recovery options may either be not appropriate in a given context while instead fitting other situations and, more than that, some conversion options based on green chemistry and biotechnology may end up being much more expensive and impacting than the conventional technology addressed, which calls for prevention more than treatment. All in all, the challenge ahead towards a preventative and regenerative eco-industrial development (Geng et al., 2014a) is not a “more of the same” approach, calling for increased implementation of “green” technologies, but instead requires a broader and much more comprehensive look at the design of radically alternative solutions, over the entire life cycle of any process as well as at the interaction between the process and the environment and the economy in which it is embedded, so that the regeneration is not only material or energy recovery but instead becomes an improvement of the entire living and economic model compared to previous business-as-usual economy and resource management. CE has the potential to understand and implement radically new patterns and help society reach increased sustainability and wellbeing at low or no material, energy and environmental costs.

Finally, it should not be disregarded that sustainability patterns (such as CE) not only require innovative concepts but also innovative actors. In fact, due to the complexity of the sustainable development vision, most often its implementation needs to be supported by innovation designers and intermediaries who provide services and designs towards appropriate radical changes in both practices, policies and decision making tools (Golinska et al., 2015; Küçüksayraç et al., 2015).

Our primary aim in this review is to summarize and evaluate the literature pertaining Chinese CE implementation experiences

and compare them with the European and Japanese as well as other worldwide experiences, to grasp similarities and differences among these geographical areas. We also provide a brief theoretical overview of CE, its origins, its underlying or foreseen economic models and its relationship to steady state and degrowth patterns that until now have challenged the present models of economic development. Our final purpose in this regard is to understand to what extent CE could be a solution to the need for reducing the environmental impacts of business-as-usual economic systems.

This study is structured as follows: Section 2 (Materials and Methods) provides details about the method used for literature mining and key characteristics of the studies selected for this review. The same section also provides an outline of CE origins, principles and models, as well as its relation with steady state, growth and degrowth patterns. Section 3 (Results) summarizes the implementation of CE worldwide on the basis of the published experiences at micro (company or consumer level), meso (eco-industrial parks) and macro (nations, regions, provinces and cities) levels in production, consumption and waste sectors as well as decoupling achievements, in China, Europe, other OECD (Japan and USA) and BRICS (Brazil, Russia, India, China, South Africa) countries. Section 4 (Discussion) discusses the main results emerged from literature and suggests directions for future research. Finally section 5 (Conclusions) highlights the key findings of the study.

2. Material and methods

The selection of published studies was performed according to several integrated criteria: (1) chronological order (from 2004 to 2014), (2) topics of interest (circular economy origins, principles, implementation at different scales (micro, e.g. company or consumer level; meso, e.g. eco-industrial parks level; macro, e.g. city, province, region, nation), (3) comparison to present economic growth and alternative patterns (steady state economy and economic degrowth), (4) problems and challenges. The literature search was performed in all web of science¹ databases and Scencedirect,² by means of keywords such as “circular economy” (758 papers), “circular economy and cleaner production” (64 papers), “circular economy and eco-industrial park” (85 papers), “circular economy and zero waste” (26 papers), “circular economy and decoupling” (11 papers), “circular economy and rebound effect” (2 papers), “circular economy and sustainability” (85 papers). Duplicate papers in more than one category were excluded, totalling 1031 papers. A first selection was made based on the content of abstracts, the representativeness of which was also weighed on the basis of the authors' names (by excluding papers with similar content) and geographical area. In so doing, 155 most representative articles were selected and grouped according to the different topics of interest for our review. Fig. 1 provides a snapshot of the different groups of topics, focusing first on two conceptual groups (CE Models and CE principles) and then on how these concepts are investigated across three main “scales” (micro: single processes; meso: eco-industrial parks; and macro: local, regional and national economies). The main conclusions of the reviewed studies are reported in the Results section. As it can be seen from Fig. 1, a large part of selected articles deals with case studies of CE's implementation at different scales while only a

¹ https://apps.webofknowledge.com/UA_GeneralSearch_input.do?product=UA&search_mode=GeneralSearch&SID=Q1Uq4F77i8P4U9Z1YsY&preferencesSaved=.

² <http://www.sciencedirect.com/>.

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