Circular Economy

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Defining the circular economy (CE) as a material and energy model coincides with the definition given by multiple authors in which Industrial Symbiosis (IS) has been deemed as a foundational strategy to support the implementation of the CE. The consumption of secondary materials is essential to achieve a successful transformation from a linear economy to a CE focused on IS practices. In this scenario, small and medium enterprises (SMEs) play a major role as stakeholders in developing CE systems as it is not possible to create this model with each company working in isolation.

circular economy industrial symbiosis

1. Introduction

The Circular Economy (CE) concept can be summarised as a paradigm shift aimed at preventing the depletion of resources by closing energy and materials loops throughout its different implementation levels: micro (enterprises and consumers), meso (economic agents integrated into the symbiosis) and macro (city, regions and governments) [1].

The practical applications of implementing this paradigm shift at different levels are rooted in different schools of thought that, taken together, shape the idea of closed loops [2]. Several authors have listed the most renowned schools of thought that refine the foundational umbrella of the CE, such as cradle to cradle, industrial ecology, biomimicry, performance economy and regenerative design [3][4][5][6][7][8][9].

In particular, industrial symbiosis (IS) as a sub-research field of industrial ecology has been described as a crucial approach to a successful CE implementation due to its capacity to provide tools and mechanisms in order to spur companies' growth while dealing with natural resource depletion [10][11][12][13]. Thus, a successful transition to a CE model driven by IS would contribute to finally closing the loop by decreasing dependence on raw materials and minimising waste from the industrial system [14][15].

However, a lack of interdisciplinary collaboration in a CE and a lack of coherence regarding how it can be implemented has been an obstacle. Some other obstacles are related to unspecified roles, lack of government coordination and low levels of participation that hinder a successful transformation. A broad collaboration of stakeholders is necessary for a CE implementation strategy that relies on the consumption of secondary products [16]. Consequently, the implementation of a local CE system requires that the interests of various partners within the value chain be aligned to achieve a circular solution [17]. Hofmann and Jaeger-Erben [18] suggest that research

should be focused on the different facets of inter-organizational relationships amongst firm units to advance a collaborative value creation network. The focus on developing local CE systems becomes relevant because this local scale could easily be mobilised for collaborative action [19]. However, it seems that there is a lack of empirical studies on the role of local stakeholders such as individual firms working in collaborative groups in the development of a local CE system [20][21].

2. Development

Although the CE and its principles are easy to understand, fully implementing them has been difficult due to their complexity [15]. Promoting a CE involves different stakeholders working in networks of relations which has also been recognized in the literature on IS [19]. Therefore, this study uses the analytical framework for the transformation from a linear economy to a CE through an IS proposed by [22] wherein IS initiatives are utilised to implement a circular system. IS has been identified as one of the practical routes for embedding CE in manufacturing activities to accelerating the transition from wasteful to closed-loop systems [23][24].

In that sense, IS enforces an approach that takes inspiration from how industrial systems mimic natural ecosystems, and it can simulate the distribution of materials, energy and information flows [25]. The proximity between companies is regarded as a critical component, as it facilitates the sharing of supplies and a reduction in transportation costs [26][27]. This may lead to better resource efficiency and a reduction in waste generation and greenhouse gas emissions. The most widely known definition is given by [28], who described IS as a system that gathers distinct industries in a joint approach to gain a competitive advantage by linking the physical exchanges of resources in a context where cooperation and synergistic opportunities offered by geographic proximity are significant.

Taking the particular features of IS, authors such as [15] have pointed out that a common characteristic of IS is the diversity of sectors involved and the multiple opportunities that could be created across value chains in diverse industrial sectors to implement a CE. Likewise, some IS efforts have been implemented on scales that differ from the typical IP or global supply chain, that is, at the facility level. This level is characterised by its small facility size, the close proximity of businesses, limits on the volume and range of available resource flows and easy-entry for small enterprises and start-up businesses, with most cases in the USA and Germany [29].

According to [30], since its origin, most IS research was predominantly theoretical (48%), however, there have been reported case studies whose content describes the research of IS in regions around the globe equivalent to 31% of the existing literature. In that regard, Asia represents the largest number of case studies reported on IS with a 49.0% share of the total, followed by Europe with a 37.5% share of case studies and North America with 9.1%.

China is undoubtedly the country with the most case studies of IS reported in the literature accounting for 34% of all publications. The countries of North and North-West Europe absorb the majority of published studies in Europe, corresponding to 72% of the total of European studies. Leading the case studies are the United Kingdom, followed by Sweden, Denmark and the Netherlands [31].

In some cases, such as Sweden, Germany, Finland, Japan and Italy, the main preconditions that allowed the creation of symbiotic exchanges were that some waste-to-resource exchanges were already implemented in the region and companies had previous capabilities in collaborative projects. And thus companies had already the required mind set, know-how and skills as well as a high level of awareness of environmental issues and legislative pressure [32].

In regions such as Portugal, Italy, Japan and Korea, other factors played a key role in their realisation, namely the local and national governments. Other stakeholders were also supportive during the creation of the IS networks; for instance, they provided funds and promoted conditions that helped the further development of the network and collaboration among companies (e.g., creating recycling norms for different types of waste in Korea). In some other IS cases, such as in China, the main precondition for IS implementation was the fact that the government had the tools to strongly influence companies' decision-making process, as well as the authority to shape the business environment [33].

Approximately 35 IS case studies in Europe have been reported in the literature, corresponding to reports in several countries such as Italy, Sweden, Germany, Denmark, The Netherlands, Finland, United Kingdom and Portugal [32][34]. IS is well-rooted in different countries, yet, the development of IS has proven to be discordant in Europe, as a result of implementing policies at a country level that are in line with a more CE which has enabled the spread of IS initiatives in certain countries [31].

European countries, such as Spain, while not having many reported cases of IS in the literature, have tried to promote programs for the adoption of IS [35].

Overall, the development of CE in China and Europe, which together accounts for the most case studies, has relied on different pathways. China's CE development is based on its large supply chain capabilities through several regional industrial agglomerations which are targeted for CE development and policies [36][37]. Whereas countries in Europe seek to create secondary materials that compete with and reduce the dependence on primary materials without considerations of scale [38][39][40]. Unlike China, the CE implementation through the creation of a European secondary materials market as part of its CE action plan [41] poses a risk for the European Union as SMEs represent 99% of its total businesses [42]. SMEs are characterized for their heterogeneity in the market which could hinder a transition to a CE system [43]. Nonetheless, SMEs involved in a CE are significantly essential to sustain higher values for the resources that cycle through the industrial system [44].

Hence, SMEs have a key role in implementing the CE, yet, the sharing of restricted technical and financial resources through networks might need to be overcome [45][46]. As SMEs only handle small amounts of resources, it is only feasible to achieve economies of scale and scope by means of IS initiatives that otherwise cannot be appropriately captured at the level of the individual firm if separately organized [16][22].

This could be one of the biggest obstacles to implement the CE system in Europe or wherever SMEs represent the majority of industrial operations as it relies on the consumption of secondary products and that absence of

engagement with these stakeholders in the implementation stage could result in a lack of support [16]. Thus, IS, in order to be widely implemented as one of the core strategies that manage resources and waste in a local CE system [47][48], will need to be based on collaboration between actors such as businesses, the community, policymakers and institutions [11]. Therefore, the cooperation within SMEs and other actors to achieve a local CE system will only be possible at the group level. Consequently, more insights are needed to tackle the potential challenges of SMEs in developing CE systems, as they tend to have a local scope with singular features [15].

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