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Circular economy actions in business ecosystems driven by digital technologies

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Abstract

Creating collaborative value through business ecosystems is crucial to achieving a circular economy model. The use of digital technologies plays a significant role in this process, as it benefits the creation of a network among different actors and has shown promise for circularity. To date, studies have been carried out on how digital technologies improve and support circular strategies and business ecosystems. However, the link between circular economy and ecosystems structured by digital technologies has not been addressed. Thus, to serve as a knowledge base for collaborative networks, this study aims to verify which circular actions have been applied in business ecosystems that use information and communication technologies, Internet of Things, and Big Data. To do this, we conducted a systematic literature review linking the research areas of business ecosystems and digital technologies. Then, real cases were selected from the published articles and reviewed in detail based on circular actions present in three well-known frameworks provided by the literature. The findings suggest that ecosystems can apply circular actions at four different levels according to DTs' degree of dependence. Also, we found there are four drivers to conduct circularity in ecosystems associated with digital transformation. Distinct types of ecosystems adopt different strategies. While the transaction type focus more on dematerialization and providing access, solution ecosystems focus on optimizing products and processes. Overall, this paper contributes to the existing literature and adds digitalization as a key aspect to conduct the transition to a circular economy, especially in collaborative networks.

Keywords: Circular economy; Ecosystem; Digital technologies; Digitalization

1. Introduction

Circular Economy (CE) is an emerging concept that has been explored in recent years [1]. CE opposes the linear economic model of production, which is based on the extraction, transformation, and disposal of waste with little or no concern about the pollution generated in the process [2]. In a CE some strategies contribute to maximizing the useful life of products and increasing resource use [3,4]. Such strategies are rethinking, reducing, reusing, dematerialize, provide results, sharing products, among others [3,5]. Another disruptive concept is digitalization, which has shown promise to CE implementation [6].

The use of digital technologies (DTs) (i.e. digitalization) in a CE enables the development of new business opportunities, improvement of existing operations [7], optimization of material flow [8], and closer and long-lasting relationships with customers [6]. However, to achieve a CE, it is necessary to look beyond individual companies, in a systemic way [9] considering an ecosystem perspective. In doing so, companies reorganize themselves into dynamic and interdependent groups that jointly create coherent solutions for the market [10].

Drawing on [11] concept, an ecosystem is "*the alignment structure of the multilateral set of partners that need to interact in order for a focal value proposition to materialize*". In general, according to [10], there are two types of business ecosystem (BE). The first one is the solution type, which has a

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focal company that orchestrates different complementors to deliver a product or service. The second one is transaction ecosystems, which is based on a (digital) platform that connects both producers and customers.

With the advent of digital transformation, those organizational structures are being changed. BE are using digital resources to facilitate their self-organization [12]. The technologies are contributing not only to increase the performance of ecosystems but also to drive solutions oriented towards circularity. However, until now, the literature does not provide a systematic exploration of how ecosystems apply circular actions in their activities or how technologies can facilitate this process. Driven by these observations, the main research question of our paper is:

Which circular actions supported by DTs are being explored in business ecosystems?

Based on this research question, our study aims to identify circular actions in real business ecosystems driven by DTs such as ICT, IoT, and Big Data. A systematic literature review was carried out in order to find evidence of circular actions used in ecosystem cases that were previously published. We provide an overview of how the circular economy is being addressed in multiple businesses. The results suggest the practicability of adopting circular strategies in ecosystems. The circular actions identified can serve as a basis and inspiration for future companies to implement circularity through a collaborative network. This paper takes the first step to explain that the adoption of a CE needs to be implemented on different levels according to the degree of dependence on DTs. Our study concludes by showing some direction for future academic studies.

2. Methodology

In order to identify the circular actions present in BE, we conducted a systematic literature review (SLR) according to [13] guidelines. This methodological approach was chosen for three main reasons. First, the SLR makes it possible to synthesize existing knowledge and identify research gaps [14]. Second, this scientific technique gathers relevant studies through a rigorous and reliable process [13]. Third, a review article serves as a basis and guide for future research [15].

The unit of analysis in this paper is the BE cases that contain circular actions and in which DTs play a crucial role. The published cases were reviewed and examined in detail based on the circular actions and strategies present in three different frameworks: 1. Resolve framework [4]; 2. circular innovation framework [3], and 3. 9R's framework proposed by [5]. These frameworks provide numerous actions that can be used to achieve circularity and enhance the potential to create value by organizations.

We selected the article's sample using Scopus, which contains many indexed journals compared to other databases [14]. The keywords used were "Business ecosystem" in combination with "Internet of Things" OR "IoT" OR "Big Data" OR "Information and communication technolog*" OR "ICT". Previous studies suggest that IoT and Big Data are promising technologies in a transition to a CE [16,17], and ICT has great potential to support sustainable development [18].

We selected only English documents from peer-reviewed journals and conferences published until September 2020. In total, 134 articles were returned. The first filter used was the reading of the title, keywords, and abstract. Documents that did not address real cases of BE supported by DTs were eliminated. This process resulted in 38 articles. The second filter was the complete reading of the papers. We excluded articles that did not have circular actions and that focus on geographic communities or clusters. A given document could report more than one ecosystem case. Thus, we evaluated a total of 8 ecosystem cases described in 7 different articles. The literature search procedure is summarized in Fig. 1.

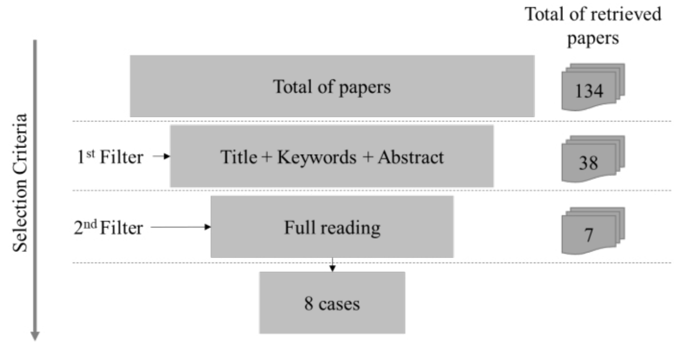

Fig. 1. Systematic literature search procedure.

3. Results

3.1. Description of ecosystem cases

We identified 8 cases describing BE that applied circular actions. The cases are heterogeneous both in the sectors actuation and the circular actions employed. All cases used DTs in their ecosystems to boost circular goals, among other utilizations. Table 1 summarizes the BE description, ecosystem actors mentioned according to the ecosystem purpose and references.

Table 1. Description of ecosystem cases.

Ecosystem Description	Ecosystem Actors	Ecosystem Type [10]	Reference
Parkeon is a parking ecosystem that uses multi-space meters to provide additional services to their consumers, such as printing tickets and making contactless payments	Manager organization (either public or private) and payment provider (such as banks and payment facilities).	Transaction	[19]
MaterialCo ecosystem employs IoT to track material information throughout its life cycle. MaterialCo gathered valuable information regarding their product and usage. This information is used to improve processes	MaterialCo, primary production companies, assembly companies, companies responsible for usage, maintenance, repair and recycling.	Solution	[20]

during the steel life cycle.			
Nest aims to provide devices to homes using IoT. Homeowners can control their preferences through an app that is connected to thermostats in their homes. This solution leads to reduced energy consumption.	Thermostat manufacturer (Nest), other equipment manufacturer (e.g. heater and cables), installation teams, energy provider and apps developers.	Solution	[21]
AcquaCloud offers solutions to small and medium enterprises regarding water refilling stations. Acqua Cloud is based on a SaaS (software as a service) mobile app that generates online water transaction reports. The app includes services such as accounts management, consumer locator, inventory, and consumer feedback.	Consumers, shop owners (water refilling), web administrators (e.g. explorer and google chrome).	Transaction	[22]
Celefish is an AI and IoT business ecosystem that monitors water conditions to fish farming. The digital platform offers online water monitoring conditions, oxygen controlling, pest controlling, energy consumption waste monitoring, and big data analysis to fishing conditions. Celefish provides data to financial institutions as a reference to credit.	Celefish, fish farming, fish farming suppliers, distributors, insurance providers and financial institutions.	Transaction	[23]
SBi is a financial ecosystem targeting several banks to improve their management and solutions. The platform allows both exchange data between banks to improve their decision-making process and solutions to consumers' focus on debit and credit cards and contactless transactions.	Banks, consumers and third parties such as payment institutions	Transaction	[24]
iCargo is a logistic ecosystem that not only synchronizes activities such as transport, warehousing but also manages pollution emission, carbon footprint, and supply chain decisions. iCargo allows companies to enhance their value proposition targeting sustainable goals.	3M (business orchestrator that objectives to enhance its value proposition), DHL (supply chain virtual integrator) and Marlo (connectivity and monitoring infrastructure).	Solution	[25]
LogiCon is a logistic ecosystem based on a multi-sided platform (MSP). MSP aims to manage the ecosystem targeting efficiency and productivity in activities such as reducing waiting time and capacity optimization.	Combi Terminal Twente (logistic operator), NexuZ (web company that manage data and data transfer) and consumers.	Transaction	[25]

3.2. Circular actions applied in business ecosystem

Our analysis of the literature identified patterns of how BE supported by DTs can apply circular actions. The actions are applied at four different levels according to the degree of dependence on DTs (Low, Medium, High) (Fig. 2). First, circular actions focused on products. Second, circular actions linked to the existing processes for delivering the ecosystem value proposition. Third, circular actions related to services offered by members of the ecosystem. And the final level is dematerialization, which crosses the first three levels. The following sections describe each one in more detail.

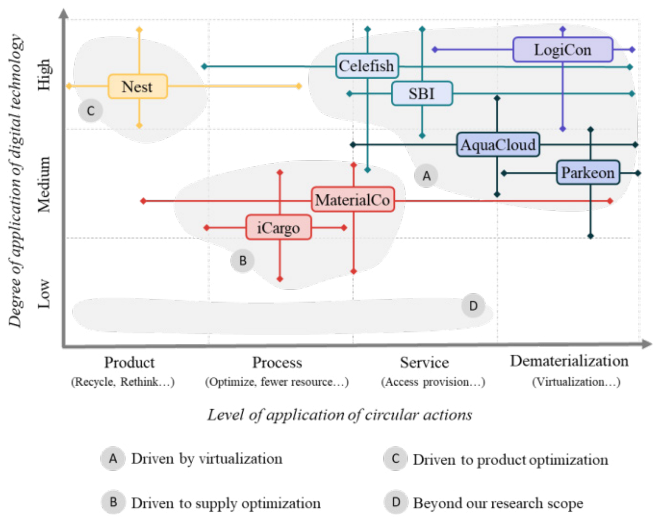

Fig. 2. Application levels of circular actions.

3.2.1 Circular actions for the product

At this level, all the strategies supported by digitalization that are applied to increase the circularity of products are presented (e.g. recycle, remanufacture, refurbish). In BE, the implementation of circular actions at this level depends on complementors. However, the effort to make products more circular is directed at the micro portion of the ecosystem that develops and applies circular actions to the product (individual company). This is the case of Nest's thermostat solution BE.

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The innovation in thermostats was based on a strategy to rethink the product by the company. With the introduction of IoT, new functionalities and features were integrated into the thermostat, allowing the monitoring of users' habits and preferences [21]. However, to deliver customer value, the heating solution developed by Nest needed other complementors, such as the building construction company and the electricity supplier (see [21]).

In the BE of MaterialCo (focal company in the steel industry), the IoT enables the material data sharing among actors, leveraging the recycling action [20]. The actors in the ecosystem need to be aligned for the exchange and sharing of information, which benefits not only those who own the data but also other participants in the network [20]. Despite the fact that both ecosystems (MaterialCo and Nest) are solution type according to [10] and associated with tangible value proposition (smart thermostat and intelligent materials), they have different degrees of dependence on IoT technology (See Fig. 2). Nest's heating ecosystem has been reconfigured to introduce digital technology. As technology was the basis for innovation, the entire ecosystem has high technological dependence. In contrast, the MaterialCo ecosystem is undergoing a digital transformation to adopt material intelligence. Although the dependence on IoT technology is not high, its introduction maximizes the possibility of future business for the different actors in the network, significantly the way of how value is created in the ecosystem [20].

3.2.2 Circular actions for the process

At this level, the circular actions applied in processes that enable the creation and delivery of ecosystem value propositions are presented. The main actions employed are optimizing and increasing the efficiency of processes using DTs. For instance, in the Celefish platform-based ecosystem [23], the feeding and production of oxygen in the fish ponds are carried out automatically by the platform, which is based on an integrated system of AI and IoT. In doing so, the ecosystem can optimize the use of fish feed and reduce the cost of electricity for oxygen production by 30% [23]. Another example is the steel industry ecosystem described by [20] that optimizes manufacturing processes by sharing data between the actors.

Pollution reduction and control was also a circular action explored by the analyzed ecosystems. According to [25], the iCargo logistics ecosystem seeks to provide sustainable value through real-time monitoring of pollutant emissions caused by road transport. Celefish's collaborative ecosystem also uses real-time tracking to control and manage water quality. The company would not be able to co-generate value without establishing direct collaboration with fish farmers to implement its ecological system [23].

3.2.3 Circular actions for the service

At this level, we considered circular actions integrated with the services provided by the ecosystem. These actions can be diverse, such as facilitating and providing access to data, goods and services, maintenance, sharing, spare parts, and others. Most circular actions at this level are employed in platform-based ecosystems (Fig. 2). Facilitating and providing access is the most used action, and its use is coherent for the operation of ecosystems since it's interesting to have data availability and integration among actors. With the support of IoT technology, the SBI ecosystem provides data for other actors benefiting the ecosystem as a whole [24].

The Celefish ecosystem provides a variety of services not only online but also offline for network participants, such as ecological aquaculture, fish pond monitoring, and sewage treatment [23]. The information generated through the platform can be accessed by other ecosystem partners such as banks to provide credit to fish farmers. Also, maintenance services are provided for installed devices and systems that support fish farming [23].

3.2.4 Dematerialization

Among all the circular actions described in ecosystems, the one that stands out most is dematerialization. Dematerialization can be understood as "the decline of material use per unit of service output", being a relevant concept for more sustainable industrial systems [26]. In a CE, dematerialization can be achieved through the delivery of functionalities virtually [4]. This is the case of ecosystems SBI, which adopted electronic payment instead of paper-based transactions [24], and LogiCon, which migrated operations to a multi-sided platform [25].

Dematerialization in ecosystems can occur through other applications such as apps and services offered. The AquaCloud Ecosystem allows platform users to make online purchases of water through a mobile application [22]. The Parkeon ecosystem concedes transactions and consulting on the internet to be carried out due to technologies embedded into multi-space meters [19]. As a result of data sharing in the MaterialCo ecosystem, simulations to test materials' behavior can be performed in laboratories using real data [20]. The advance of digitalization allows new functionalities in the form of value to be delivered to members of the ecosystem without increasing material use.

3.3. Digital drivers for circularity in business ecosystems

Based on the analysis of the previously published ecosystem cases, we found four drivers to conduct circularity in ecosystems associated with digital transformation (Fig. 2). Each driver influences how ecosystems are structured. It is relevant to this clusterization how the company delivers its solution to the market and how the CE-actions depend on DT. These actions can have an impact on micro, meso, and macro levels. At the micro-level, the actions are implemented by one actor with the support of others and have an impact on the consumer side. At the meso level, the effect is perceived by more actors in the ecosystem. And, finally, at the macro level, the impact is on a wide scale. The cluster of each one is addressed in the following sections.

3.3.1 Driven by virtualization (Cluster A)

Cluster A sums up ecosystems oriented to virtualization offerings. This ecosystem type only exists due to DTs employment, which in some cases give them innovative features regarding their ecosystem value proposition. The ecosystem focus is to provide digital solutions with more agility and consequently minimize resource consumption. Circular actions in these ecosystems have a macro-level impact, i.e., there is an easiness to influence consumers and complementarities towards a more sustainable attitude. Due to the cluster A influence, we firmly believe this ecosystem configuration can attract participants that also are circularity-oriented through DTs.

3.3.2 Driven to supply optimization (Cluster B)

The second cluster (B) in our analysis are ecosystem driven to supply chain optimization. These ecosystems do not have high technology dependence to survive on the market, however DTs can provide a differential to these ecosystem circularity actions expansion. The impact amplitude of their activities to CE is meso-level since the actions affect participants both upstream and downstream. Our study indicates that these ecosystems are mainly focused on boost their efficiency and improve their process quality, which is directly associated with circular initiatives.

3.3.3 Driven to product optimization (Cluster C)

Cluster C represents ecosystems driven to product optimization aiming to materialize solutions into tangible goods project to be circular. The performed circular actions have a micro-level impact. This characteristic does not mean that these ecosystems are less circular but reinforces the importance of a focal company responsible for designing a product that can influence the clients' usage patterns behavior and potentialize waste reduction of end consumers. The consumer relationship is essential to achieve the circular goals properly. The product will demand a higher technological dependence, and the ecosystem members will be structured to support both product delivery and collection to direct it to new paths.

3.3.4 Ecosystems beyond our research scope

In this paper, we focus on BE that use ICT, IoT, and Big data to support circular actions. It goes beyond our research scope to analyze networks of actors with little or no dependence on the technologies mentioned (Cluster D). However, we recognize that these other ecosystem configurations may adopt circular strategies. This is the case of Amsterdam's port ecosystem, which has several companies carrying out activities for processing, recycling waste, and metals [27]. Future studies may concentrate efforts to analyze these specifics ecosystems.

4. Discussion and Conclusion

This study highlights circular actions in BE that are enabled by DTs. Through an exploratory review of ecosystem cases published in the previous literature, we suggest that circular actions can be applied at four different levels, namely product, process, service, and dematerialization. Transaction ecosystems are more focused on service and dematerialization, while solution ecosystems adopt more strategies associated with products and processes. However, both ecosystem configurations can effectively leverage the CE through digitalization.

Interdependent actors around a technological solution are highly dependent on DTs compared to BE that are moving towards digital transformation. In addition, our study shows that its necessary to take a micro, meso, and macro view of the circular economy within the BE. Different players may not focus only on strategies such as access provision if the products were not designed to be circulated in the system. Nest, as a company, rethought the uses of the thermostat and needed an ecosystem approach to materialize the value proposition [21].

For society to move forward sustainably and BE to become circular, there is still a long pathway. Products must be rethought, processes optimized, complementors and orchestrator should be aligned with a collective vision of creating environmental and economic value. Previous research has shown the potential of ecosystems to boost CE [27,28]. This study contributes to this existing literature and adds digitalization as a key aspect of this transition. We encourage future empirical research to analyze whether the current BEs are prepared to be circular and how fully digital ecosystems can contribute to this new economic model.

This study has some limitations. First, we have not evaluated BE that are considered circular. It was a first attempt to identify how real ecosystems are implementing CE-actions. The transition to a circular economy still requires a critical change in the way how organizations are structuring themselves. Second, only ICT, IoT, Big Data were considered to select the sample cases. There is great potential to boost the CE through DTs that were not explored in-depth in this study, such as Blockchain [29], and AI application [30]. Further research could address these digital technologies.

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