THE ROLE OF DIGITALIZATION IN ACCELERATING THE TRANSITION TOWARDS A CIRCULAR ECONOMY

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DOI: https://doi.org/10.36004/nier.cecg.III.2023.17.27

Abstract*. In this article, it is shown that the lack of a proper digitization in the economy leads to the disruption of the transformation of the value chains, the change of the structure and the functioning of the markets, components necessary for the implementation of the circular model. Good digitization facilitates, through its technologies, the transition to the circular economy through the collection, management and processing of data, the creation of platforms, all of which influence consumer behavior and the way relationships are developed, maintained and advanced, thus increasing value retention and mitigating some of the externalities environmental. The article also analyzes the main economic sectors and sub-sectors in which circular economy measures can be implemented with the help of digitization, which support policies not only by identifying the focal points that can bring the most benefits, but also by reporting them to the broader perspectives of pledged contributions such as Nationally Determined Contributions (NDCs) and other benchmarks such as national carbon budgets.*
Keywords: *digitalization, transition, circular economy, polluting economic sectors, benefits*
JEL: *P48, Q01, Q53*
UDC: *338:004*

Introduction. A circular economy preserves the added value of a product as much as possible, even when the product has reached the end of its life cycle, so that the materials it is made of are used productively and continue to generate value. It aims at the efficient use of flows of materials, energy, labor and information, so that natural and social capital can be reconfigured

The transition from a linear to a circular economy involves a substantial departure from the industrial status quo and will require interdisciplinary collaboration to succeed. In addition, vis-à-vis manufacturing companies, policy makers and investors need to support the idea of bringing about large-scale changes in current practices. Moreover, research and development of new processing and remanufacturing methods must be stimulated to meet the particular technical challenges.

The circular economy is based on a few simple principales:

- a circular economy aims to eliminate waste, products are designed and optimized for a cycle of disassembly and reuse. These components as well as product cycles define the circular economy.

- the concept of circular economy is based on the study of the real world, consisting of non-linear feedback systems.
- circularity introduces a strict differentiation between consumable and durable in the components of a product. Unlike the linear model, in the circular model consumables are mostly made of components that are not toxic and that can safely return to the environment, either directly or in a cascade of consecutive uses as durable goods. They are designed from the start for reuse, they can be easily improved from a technical point of view (upgraded).
- circularity leads to breaking the link between resource scarcity and economic activity by using only resources that can be continuously regenerated for productive use. These circular economy principles aim to create sources of value, which provide arbitrage opportunities, or in other words, ways to take advantage of the price difference between materials used for the first time in production and recycled materials. Sustainable resources, liquid markets, long product life cycles and value chains constitute the areas of value creation in the circular economy.

Digitization is a tool to accelerate the implementation of the circular economy and its models. It is transforming economies and societies by changing the way people interact with physical and virtual assets (OECD, 2017). It also changes the nature of the assets that generate value, how their ownership is transferred and where value is generated.

In other words, digitization and digital technologies enhance the implementation and development of the circular economy by creating opportunities in the transformation of value chains, by facilitating the more efficient use of natural resources.

Literature Review. Numerous researchers have been concerned with studying the creation of the main opportunities of digitization in the implementation of business models based on the circular economy.

In 2016 Moreno M. and Charnley F., discussed in their paper the potential to reduce the use of natural resources by introducing digital technologies that can facilitate circular systems.

Perhaps the most important facilities are provided by digitization through digital technologies in the industry, having a significant contribution to the efficiency of the use of resources, energy consumption, logistics routes and their capacity to use them. Digital technologies also enable the optimization of product life cycles and access to data on product tracking along the value chain and waste streams.

According to (Pagoropoulos et al., 2017), the collection of information related to a product facilitates the estimation of the quality of the products when they are returned, access to data on the type of material and constituent components, facilitating the quality of returned products and return flows in management product life cycle.

Three years later, (Ingemarsdotter et al., 2020) shows that digital technologies improve the collection, storage and monitoring of information about the residual value of products and thus help to improve cost efficiency.

Digitization in his opinion (Pizzi et al., 2021), thus translates into lower costs and increased cash flows.

Digitization offers opportunities for the virtualization of distribution channels, value can be passed on to buyers and, with the help of circular models, lead to the reduction of environmental impact.

Digital technologies that mitigate market imperfections. By studying specialized literature, we obtained four categories of market imperfections that prevent access and increased transparency of data collection, processing, storage and analysis of materials, components, processes, products and services, as well as the creation of information and knowledge for automated decision-making , optimized sharing of assets, reduced and simplified transaction costs, in other words, accelerating the transition to circular models (Figure 1).

Figure 1: Market imperfections that hinder the transition process towards the circular economy

Sorces: autor conception

Digital technologies that lead to a circular economic transformation were identified and defined in an OECD report in 2018. Thus, the following digital technologies were identified:

- Internet of Things (IoT) - connects objects and sensors that gather and exchange data;
- Big data analytics - allows processing and interpreting large volumes of data;
- Artificial intelligence (AI) - allows machines to perform human-like cognitive functions;
- Blockchain - facilitates transactions and interactions through decentralized and immutable

information exchange;
- Cloud computing - offers services of computing resources over the Internet;
- Online platforms - enable innovative forms of production, consumption, collaboration and sharing, through interactions among and between individuals and organizations.

With the help of Internet of Things (IoT) technology, data is collected about the complex functionality of the product in the circular economy to provide a wide variety of functions and/or to provide better functionality over time, which leads to a greater number of materials . Thus, information is needed related to the condition and availability of materials, components and products, and the composition of waste streams and the quality of secondary materials. They are often incomplete, asymmetric or missing altogether.

The Internet of Things (IoT) will enable customers to access raw material information, identify products, examine material properties, download material certificates and provide feedback.

The lack of manufacturing information, repair instructions and recycling conditions can be remedied by digitizing goods labels attached to waste and recycling containers that help collect data on when they are full, alerting haulers to send a vehicle to collect them. empties, as well as to ensure the verification of the service and the route, by managing the waste vehicles and informing the waste sorters, recyclers and buyers of secondary materials.

Artificial intelligence (AI), big data, and the cloud are considered to be core transformative technologies with broad applications across multiple industries, while sectors such as manufacturing are embracing specialized robotics.

There is insufficient information about the origin and quality of secondary materials, and the creation of a digital passport helps to identify different types and grades of materials during the disassembly process in the landfill and therefore allows improving the recovery and reuse of materials and reducing the dependence on those materials non-renewable and expensive.

The lack of data on the collection, sorting, and processing of waste, the lack of data on the composition of the material produced, properties and processing, can be compensated by tracking the supply chain for better product traceability and to allow protecting the reputation of producers, to inform customers or to ensure the quality and authenticity of the products as well as the supervision of those responsible for the supply of raw materials.

In the process of transition to the circular economy, an important role is played by Data Collection, Data Integration and Data Analysis (Figure 2).

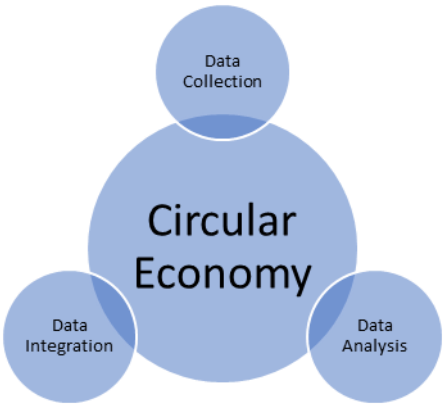

Figure 2: Data Collection, Data Integration și Data Analysis - părți componente ale procesului de tranziție spre economia circulară

Sorces: autor conception

Data collection

Radio Frequency Identification (RFID) uses electromagnetic fields to automatically identify and track tags attached to a product. In the context of the circular economy, RFID helps track material flows to enable value recovery through the implementation of Reuse, Repair, Remanufacturing strategies.

The Internet of Things (IoT) are connectors of networks to computing systems that can monitor or manage the production processes of various products. In the circular economy, IoT can collect information to connect to existing production processes along the value chain and describe circular economy patterns as dynamic feedback in control loops.

Also, IoT provides information about products or their components throughout their lifetime.

Data Integration

Data integration refers to relational database management systems and database processing systems that support the objectives of the circular economy.

Product Lifecycle Management (PLM) systems store, process and transmit information about data, process, business systems. They help move the circular economy, help integrate information across multiple life cycles and between different parts of the value chain.

The role of data in the circular economy. The circular economy must be a data economy, and climate and sustainable resource consumption must become an integral part of digital management systems. Digital solutions allow people to connect with each other, work and transfer a very large volume of data in a very short time.

Circular economy methods are highly scalable, therefore it is able to increase growth and attract investment capital.

Thus, incorporating the attributes of the circular economy, in the research-development-operations phase, leads to advances in the field of material sciences and to the production of higher quality and more durable components.

One of the barriers to increasing the scalability of the circular economy is the lack of information (market inefficiencies) about the nature of the materials that make up a product, the data required for its maintenance, lifetime and recycling, the stock of materials that can and which are available in the market.

Sustaining a process of systemic transformation has its origin in digitization and technological changes that influence the way the economy is made and organized.

Artificial intelligence, the transfer and analysis of metadata, the Internet of Things, online platforms, the recording of transactions made in bitcoin or other cryptocurrency are flows of information provided with the help of digitization through its technologies.

Digital technologies that can be considered tools of the transformation of the economy and the implementation of circular models are : Cloud computing, which offers computing resource services via the Internet, Online platforms that allow innovative forms of production, consumption, collaboration and sharing through interactions between and between individuals and companies . Internet of Things (IoT) – which connects objects and sensors that collect and exchange data, Big data analytics that processes and interprets metadata, Artificial Intelligence (AI) that enables machines to perform human-like cognitive functions, Blockchain that facilitates transactions and interactions through exchange of information and online platforms that enable innovative forms of production, consumption, collaboration and sharing.

It is necessary to promote environmentally sustainable life cycles in which materials are used economically, substituting a base material with the help of 3D printing. In this way, the collection of waste resulting from the expiration of the product's life, the sorting and recirculation of reusable materials is facilitated.

The lack of information on maintenance and repairs can be solved with the help of the Internet of Things (IoT), cloud computing, and big data analysis.

Digital technologies such as artificial intelligence (AI), Internet of Things (IoT), big data analytics, cloud computing, blockchain, online platforms and 3D printing can power the transition to the circular economy by generating information flows.

Examples of circular economy activities enhanced by the implementation of digital technologies can be found in Table 1.

Table 1: Examples of circular economy activities enhanced by the implementation of digital technologies

	IoT	Artificial Intelligence	Big Data Analytics	3D Printing	Online Platforms	Cloud Computing	Blockchain
information necessary to identify the origin and authenticity and quality of materials and products					x	x	x
information needed to track materials and products				x			
information needed to track components and products for maintenance and repair	x		x		x	x	x
Information needed to condition based manufactoring and descentralised manufactoring	x		x	x	x	x	
Digital passports to support disassem-bly, reuse and recycling			x		x	x	x
Tracking of waste for better collection and recycling			x		x	x	x
Asset sharing platforms	x	x			x	x	
Demateriali-zation and product as a service	x				x		x
Materia exchange platforms		x	x		x	x	
Manufac-turing a service			x		x		
Enhanced product information for mmare informed consumer choices		x			x		
Enhanced tools and data for product and materials design				x	x		
Enhanced tools and data for dismanting and material recovery		x	x				

Sorces: autor conception

Digital transformation needs to be targeted towards digitization-related reforms and investments in national recovery and resilience plans. This is an unprecedented opportunity to accelerate digitalisation, increase the resilience of the economy and reduce external dependencies through both reforms and investment.

Conclusions. The digital transition is a key element for the strategic autonomy of any country, it plays an important role alongside the circular economy. Digital technologies are able to fundamentally change existing business models, their use provides the ability to flexibly use remote resources for the purpose of storing and processing data on demand, which substantially reduces infrastructure costs. These tools ensure the efficient work of online teams and allow storing large amounts of data, as well as maintaining its security at the highest level.

Digital technologies also give informational value to data on production and supply issues, defects, rates, product useful life, consumer complaints and usage patterns can be found more easily in a closed-loop system.

Thus, this information can be used to improve various processes such as: product design, production, etc.

In terms of life cycle stages, digital technologies can help close the material loop, so important support is given by information at the end of the product life and in connection with production.

Digital technologies also play an important role in the simulation, optimization and dynamics of circular models, thus leading to higher recovery rates of materials or product components. We can say that in this way in production it is possible to monitor, control and optimize stocks and material flows much better.

In conclusion, digital technologies play an important role in the transition to a circular economy by optimizing material flows and enabling reverse material flows. In this regard, there is a gap between the data collected, their integration and their analysis.

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