HOW DIGITALIZATION, CIRCULAR ECONOMY AND DECARBONIZATION INTERCONNECT TO SUPPORT SUSTAINABLE ECONOMIC DEVELOPMENT

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Abstract

This article analyzes the interdependence relationships between digitalization, circular economy and decarbonization, three concepts that characterize the structural transformations that are taking place in the contemporary transition towards sustainable economic models. The objective of the research is to explain how digitalization accelerates the implementation of circular models in the economy for the efficient use of resources and to what extent decarbonization represents the result of the resulting effect of these processes.

Based on the research of the specialized literature, it is shown that digital technologies facilitate the traceability of resources, the optimization of production chains, the transformation of traditional products into smart services. It is thus considered that digitalization accelerates the transition to the circular economy, by extending the life cycle of products, indirectly generating the reduction of pollution, greenhouse gases, and implicitly climate change. The research results show that decarbonization manifests itself as a result of the interaction between digital technologies and the adoption of circularity. The conclusions underline the need for an integrated approach, as limitations associated with digitalisation, such as infrastructure disparities and risks generated by the energy consumption of technologies, can influence the pace of the transition. The analysis shows that the interdependent relations between the three concepts constitute the foundation of the green transition in the European Union and of the redefinition of production, consumption and value creation models, orienting the economy towards sustainability, from ownership to use.

Keywords: *digital technologies, circular business models, resource management, carbon emission reduction, sustainable transition*

Classification JEL: *O33, Q55, L21*

1. Introduction

The transition to a smart circular economy has generated an increasing interest in adopting digital solutions. Emerging technologies are becoming essential tools in efforts to reduce environmental impact, especially with regard to decarbonization.

The paper has three main objectives: conceptual clarification of the analyzed notions and identification of their defining elements, explaining the mechanisms through which digital technologies facilitate the application of circularity principles, and interpreting decarbonization as a result of the interaction between digital innovation and the reorganization of material flows.

The analysis is based on a conceptual approach, integrating recent contributions from international literature, as well as European Union strategies.

In the last two decades, the structural transformations of economies have been marked by two major directions: accelerated digitalization and the transition to sustainable economic models, capable of reducing dependence on finite resources and the impact on the environment. In this context, the concept of the circular economy has emerged as a new framework for organizing economic processes, and digitalization has become an important factor in this transformation. These developments are closely linked to the global decarbonization objectives, which aim to reduce greenhouse gas emissions and achieve long-term climate neutrality.

2. Interdependence Relationships Between Concepts

The transition to a sustainable economy cannot be understood without analyzing the complex interaction between digitalization, circular economy and decarbonization. These three concepts do not operate in parallel, but support each other in a dynamic way, generating cumulative effects at the economic, technological and climate levels.

Digitalization provides the technological infrastructure necessary to operationalize circularity, the circular economy provides the structural framework for the efficient use of resources, and decarbonization is the ultimate goal of this transformative process.

Table no.1. highlights the essential relationships between the three concepts at the heart of contemporary economic and social transformations: digitalization, circular economy and decarbonization. These concepts, although distinct in terms of application, are interconnected and contribute complementary to accelerating the green transition.

Table no. 1. Comparative synthesis of concepts

Element	Digitalization	Circular economy	Decarbonization
Main characteristics	Technological and economic	Systemic and economic	Climate and energy
Strategic objective	Structural transformation of economic processes	Maintaining the value of resources	Reducing GHG emissions
Link to sustainability	Efficiency, traceability, reducing waste	Reducing waste, material regeneration	Climate neutrality
Role in the green transition	Catalyst for circularity and decarbonization	Contributes to reducing emissions indirectly	Strategic target of the ecological transition

Source: author's conception

Digitalization acts as a facilitator of the transition to a circular economy, offering advanced mechanisms for data collection and analysis, resource traceability and the possibility of optimizing production chains. Through these mechanisms, digitalization contributes to reducing the waste of materials and energy, which generates an indirect effect on carbon emissions.

The circular economy, in turn, creates the structural conditions for decoupling economic growth from resource consumption and emissions. Through strategies such as reuse, remanufacturing or extending the life of products, circularity reduces the pressure on primary production, which is often the most energy and emissions-intensive. Digitalization intensifies these effects, making possible data and algorithm-driven production and consumption models in which resources are managed efficiently.

Decarbonisation is therefore an emerging outcome of the interactions between digitalisation and the circular economy. To the extent that digital technologies contribute to the development of efficient circular models, they facilitate the reduction of emissions and the achievement of climate objectives. The relationship is bidirectional: decarbonisation objectives stimulate investments in digitalisation and circular models, and these transformations support the achievement of climate objectives. This integrated framework can be understood as a systemic transition, in which technology, economy and environmental policy support each other.

Decarbonisation is distinguished by pronounced climate and energy characteristics, representing one of the most important strategic targets of the ecological transition. Its fundamental objective is to reduce greenhouse gas (GHG) emissions, with a view to achieving climate

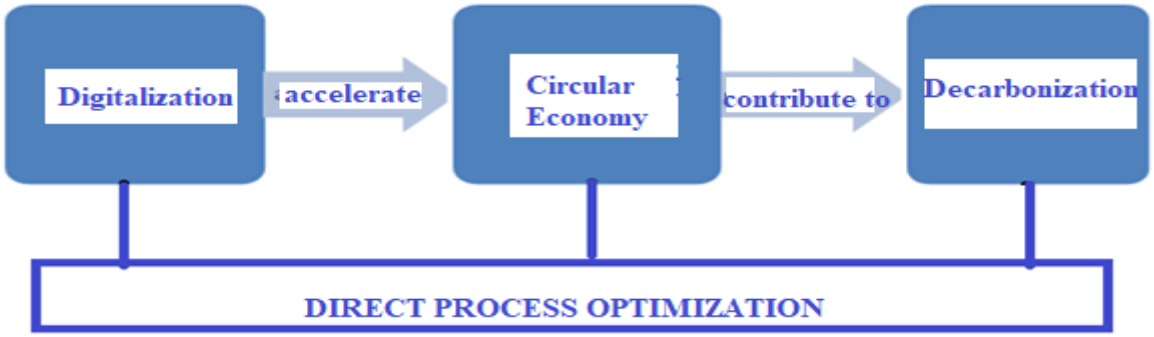
neutrality. However, decarbonisation cannot be achieved in isolation: it depends on efficient digital infrastructures to ensure accurate monitoring and reporting of emissions, as well as on the adoption of circular economy principles to limit resource use and prevent the generation of indirect emissions. The interdependence between digitalisation and decarbonisation reflects a systemic transformation: climate pressures drive technological development, and technology, in turn, creates opportunities for reducing emissions and increasing economic resilience.

Therefore, the comparative analysis of the three concepts shows that digitalization provides the tools, the circular economy provides the model for sustainable resource use, and decarbonization is the ultimate goal of the green transition. Together, these dimensions outline an integrated framework for sustainable development, in which technology, economics, and climate policy complement each other to ensure a profound structural transformation with long-term effects on the environment, society, and the global economy.

3. The Transition To A Sustainable Economy In The European Union

The transition to a sustainable economy in the European Union is based on an integrated conceptual model, in which digitalization acts as a catalyst, the circular economy is the main implementation mechanism, and decarbonization is the final strategic objective of the ecological transformation, is presented in Figure no. 1.

Figure no. 1. Integrated conceptual model



Source: author's conception

The model highlights the two-way relationships: digitalization supports both circularity and decarbonization directly, while circularity becomes the main vehicle for reducing emissions and using resources efficiently. It describes a dynamic relationship between the three dimensions, in which digitalization accelerates the implementation of circular economy principles, which in turn significantly contributes to the decarbonization process. At the same time, digitalization exerts a direct influence on reducing emissions by optimizing industrial and energy processes, thus creating a two-way link between all three pillars. These interdependencies generate profound transformations in the economy, which occur against the background of the integration of emerging technologies and the change in production and consumption models. They determine the emergence of new, more flexible and sustainable value chains, based on data and energy efficiency. In this context, companies are forced to reconfigure their business strategies, emphasizing innovation, collaboration and reducing their carbon footprint. Table no. 2. summarizes the main directions of economic transformation generated by the interaction between digitalization, circular economy and decarbonization.

Table no.2. Profound transformations in the economy that are taking place

Concept	Key aspects
Digitalization	- Resource efficiency
	- Material traceability
Circular Economy	- Emission reduction
	- Reuse
	- Regeneration
	- Loss minimization
	- Alternatives to the linear model
Decarbonization	- Carbon footprint reduction
	- Technological, structural, behavioral measures

Source: author's conception

Each of these concepts contributes to the creation of a more sustainable economic model, based on efficiency, reuse and reduced environmental impact. Together, they define a deep structural transition towards a green and resilient economy. These structural transformations align with European policy trends and objectives, where digitalisation, the circular economy and decarbonisation are becoming central pillars of the green transition.

In this context, the European Union has created a coherent strategic framework, which integrates the economic, technological and social dimensions of sustainability. The European Union's response to the global climate crisis is embodied in major initiatives such as the European Green Deal, the "Fit for 55" legislative package and the Circular Economy Action Plan, documents that define the directions of action to achieve climate neutrality, while stimulating technological innovation, energy efficiency and the sustainable competitiveness of the European economy.

The interdependence between digitalisation, circular economy and decarbonisation is therefore reflected in the European Union's strategic vision for the green transition. This integrated approach reflects efforts to build a fair and competitive economic model, geared towards climate neutrality and resource efficiency.

This economic transformation involves, first of all, redefining the ways of creating value: products become "smart services", and the life cycles of goods are extended through digital monitoring, connectivity and feedback-data-driven, which reduces the intensity of resources and energy used. For example, a digitalized production model allows for real-time inventory management, product wear monitoring and optimal maintenance scheduling, thus reducing losses and optimizing infrastructure utilization.

Digitalization also has a business innovation component: models such as pay-per-use services, peer-to-peer sharing, connected products that communicate their status are emerging, which reduces the need for repeated production and stimulates an economy based on access rather than ownership. In this sense, research suggests that digitalization plays a key role in economic sustainability, as digital technologies can stimulate the circular economy, and through it, the sustainable economic model.

4. Conceptual Limitations

The transition to a sustainable economic model based on digitalization, circular economy and decarbonization generates clear benefits, but there are also a number of challenges.

Digitalization involves considerable energy consumption, as digital infrastructures, data centers and connected devices can contribute to an increase in the carbon footprint if they are not powered by green energy (OECD, 2024).

Another important aspect is the rebound effect: the increased efficiency generated by digital technologies can lead to an increase in total consumption by expanding production and access (Trevisan et al., 2023).

In addition, disparities between developed and emerging economies can exacerbate technological and environmental gaps. The lack of digital infrastructures and adequate skills can delay the transition to circular models and decarbonization processes in some regions. At the same time, it is necessary to consider issues related to data security and the protection of critical infrastructures.

All these aspects, highlighted in the chapter, contribute to shaping an integrated approach, in which digitalisation, the circular economy and decarbonisation are not isolated processes, but complementary dimensions of a coherent European strategy for the transition to sustainability. The difficulties of this transition should not be ignored either, as the adoption of circularity implies profound changes in business models, investments in infrastructure and behavioural changes at the consumer level. However, the long-term climate and economic benefits outweigh these initial costs, transforming the circular economy into a central tool for decarbonisation.

5.Conclusions

The analysis demonstrates that digitalization, circular economy and decarbonization form an integrated system, essential for underpinning the transition to a sustainable economy. Each of these dimensions has a distinct function, as a technological infrastructure, an economic system, a climate objective, but only their interaction generates the transformation necessary for the transition to sustainable development.

The article also highlights the challenges and tensions that stand in the way of the transition. These include the energy consumption of digital infrastructures, the rebound effects of efficiency gains, inequalities in access to technology, the lack of digital skills and the costs of adapting to circular models.

The transition also involves cultural, institutional and economic changes that cannot be implemented uniformly, and disparities between developed and emerging economies can exacerbate technological and environmental gaps. The lack of appropriate digital infrastructures and skills can delay the transition to circular models and decarbonisation processes in some regions. At the same time, it is necessary to consider issues related to data security and the protection of critical infrastructures. The result is that, although the synergies between digitalisation, circularity and decarbonisation are clear, the pace of transformation depends on the capacity of economies to integrate technologies and reform economic processes.

6.Bibliography

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