TESIS DOCTORAL

Building Circular Supply Chains

From An External Capital Perspective

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Al amor de mi vida,

por su paciencia y cariño infinitos.

To the love of my life,

for his infinite patience and love.

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“Sólo cuando el último árbol esté muerto,

el último río envenenado y el último pez atrapado,

te darás cuenta de que no puedes comer dinero”

Sabiduria indoamericana

"Only when the last tree is dead,

the last river poisoned and the last fish trapped

you will realise that you cannot eat money."

Indoamerican wisdom

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Resumen

La economía circular rompe con la economía lineal tradicional, ofreciendo un sistema regenerativo y restaurativo, a través de cadenas de suministro de circuito cerrado. Las cadenas de circuito cerrado implican la devolución de los productos al final de su vida útil para su reutilización, reparación, reacondicionamiento o reciclaje, siguiendo con los principios circulares. Esta temática en la actualidad resulta de gran interés para la comunidad científica, debido al componente económico, social y medioambiental que atiende. Existen trabajos previos publicados que relacionan la sostenibilidad con el capital intelectual, pero aún hay una laguna existente en la literatura actual con respecto al estudio que vincula la circularidad con las relaciones que se llevan a cabo en la cadena de suministro, lo cual aborda la presente tesis doctoral.

El objetivo de esta tesis es estudiar la asociación entre las cadenas de suministro y la economía circular desde el punto de vista del capital intelectual externo, haciendo hincapié en la cooperación y la colaboración de las empresas con los proveedores y los clientes. Buscando llenar este vacío en la literatura, este trabajo analiza los siguientes aspectos: 1) el papel que desempeñan los recursos intangibles en la implementación de las cadenas de suministro circulares; 2) cómo influye el capital externo en las cadenas de suministro circulares; y 3) cuáles son las principales temáticas de investigación en la gestión circular de los residuos alimentarios.

La tesis doctoral se ha llevado a cabo por compendio de tres artículos científicos publicados en revistas de impacto. En el primer artículo se ha realizado un estudio empírico para profundizar en la capacidad de absorción de las cadenas de suministro circulares utilizando la dimensión de explotación. En el segundo artículo, se ha analizado, a través de una revisión sistemática de la literatura, la resiliencia de las cadenas de suministro circulares, siguiendo el enfoque del capital externo. Por último, en el tercer artículo se ha desarrollado un análisis bibliométrico para examinar el estado del arte en el campo de la economía circular y la gestión de residuos alimenticios.

Los resultados obtenidos ofrecen oportunidades para la implementación de los principios de la economía circular, indicando las posibilidades de su aplicación y complementando las investigaciones ya existentes en la literatura. El primer artículo

muestra que la gestión del conocimiento desempeña un papel clave en la aplicación de las cadenas de suministro circulares. Una eficiente gestión de los flujos de conocimiento afecta positivamente a la competitividad y a la capacidad de innovación de una empresa. El modelo conceptual propuesto en el segundo artículo acerca de las relaciones entre los proveedores y los clientes, relacionado con la resiliencia y la implementación de cadenas de suministro circulares, proporciona un marco de referencia para la literatura científica en este ámbito. El tercer artículo arroja luz sobre la estructura cognitiva e intelectual sobre la gestión circular de los residuos alimentarios, dando a conocer las principales áreas y temáticas más estudiadas, además de las nuevas tendencias, ofreciendo una agenda con oportunidades futuras de investigación en este ámbito.

En conclusión, la cooperación y la coordinación entre los distintos agentes de la cadena de suministro es fundamental para la implementación de los principios circulares. Esta tesis doctoral pretende llenar el vacío existente en la literatura a través de los tres artículos expuestos. Teniendo en cuenta que la aplicación de prácticas circulares en las diferentes etapas dentro de la cadena de suministro y su implantación en distintas industrias es un aspecto en constante evolución, este trabajo supone un punto de partida para futuras investigaciones.

INTRODUCTION

INTRODUCTION

I. Research aim and thesis structure

The aim of this thesis is to analyse the relationship between supply chains and the circular economy from an external intellectual capital point of view, with an emphasis on the collaboration and cooperation of organisations with suppliers and customers. The scientific publications that shapes the relationship between external capital and circular supply chains is scarce, but of great interest to the scientific community, so the objective is to fill this gap in the literature.

Hence, the following research questions are exposed:

RQ1. What role intangible resources play in the implementation of circular supply chains?

RQ2. How does external capital influence the dynamics of circular supply chains?

RQ3. What are the main areas of research in circular supply management in food supply chains and what are the future research opportunities in this field?

This doctoral thesis has been conducted by compiling three articles published in impact journals indexed in *Journal Citation Reports* (JCR) and *Scientific Journal Rankings* (SJR).

The first article answers the first question by carrying out an empirical study to deepen the performance of the circular supply chain using the exploitation dimension of absorptive capacity, distinguishing between routines that allow adaptation to new production needs -technological knowledge- and new commercial needs -market knowledge-. For this purpose, PITEC panel data from Spanish manufacturing companies of different technological levels and sizes have been used. The results show that the operational routines associated with the use of production and logistics technologies developed in a circular way favour the development of new products.

The second paper answers the second research question performing a systematic literature review that associates circular supply chains to resilience from an external capital perspective. In this paper, an exploratory and conceptual model is developed to establish the link between supplier choice and consumer purchasing behaviour, from a collaborative and environmental coordination point of view, to implement more circular and sustainable practices.

To answer the third research question, the third article focuses on the application of the circular economy in a specific sector, food waste management. A sustainable food system is fundamental to achieve the Sustainable Development Goals (SDGs) focus on minimise food waste at the consumer stage and food loss in the production level. This reduction supposes economic, social and environmental benefits following the circular economy principles (Närvänen, Mesiranta, Mattila and Heikkinen, 2020). A bibliometric analysis is carried out to examine this state-of-the-art, from a holistic point of view, using a co-word analysis. The main themes and emerging trends are identified, proposing a future research agenda for this field of study.

In this introduction section the conceptualisation and the state-of-the-art that links circular supply chains with intellectual capital, in addition to the association of circular principles in food waste management are presented. Subsequently, the three articles above mentioned that comprise the thesis are exposed. The doctoral thesis ends with the conclusions section where the academic contributions, practical contributions and future research lines are presented.

II. Conceptualisation and state-of-the-art

2.1. Circular economy

Circular economy breaks with the paradigm of ‘produce-take-dispose’ adopted by the traditional and linear economy (Goyal, Esposito and Kapoor, 2018). Pearce and Turner (1989) presented the concept of the circular economic system influenced by the work of Boulding (1966), which argued that the Earth should be considered as a closed loop to achieve a balance between the economy and the environment. Many scholars have pointed out that the concept has its origins in China (Liu, Li, Zuo, Zhang and Wang, 2009) following the industrial ecology paradigm.

Circular paradigm is a restorative and regenerative economic model that replace the concept of "end of life", seeking to maintain resources and their value for as long as possible. It pursues to reduce negative effects on the environment by reducing and eliminating waste, reduction of resources and closing the loop (Ellen MacArthur Foundation, 2014). This system aims to minimise energy emission and leakage by tightening energy and material loops, following the material balance principle (Andersen, 2007) based on recycling, reuse, refurbishment and remanufacturing (Geissdoerfer, Savaget, Bocken and Hultink, 2017). The most important issue is that many policies only focus on recycling (Ghisellini, Cialani and Ulgiati, 2016).

Circular principles promote the environmental and sustainable rational use of resources for a greener economy, by means of new business models (Ellen MacArthur Foundation, 2012). This economy is based on the spiral system, which minimises the flow of energy, as well as the environmental degradation, without affecting or reducing economic, social growth and progress (Lieder and Rashid, 2016). The circular economy adopts a cradle-to-cradle approach targeted on reuse and recycling products, avoiding material waste, reducing waste management problems, reducing pollution and creating new employment opportunities (Ellen McArthur Foundation, 2012). The development and implementation of a circular economy system provides an improvement of the current business model towards an eco-industrial and regenerative one (Ghisellini *et al.,* 2016).

2.2. Intellectual capital and supply chains

Intellectual capital refers to assets and resources that enable firms to create value (Grant, 1991). Intellectual capital can strengthen the management of organisations, improving social, economic and environmental performance. It is understood as the compilation of capabilities and intangible assets that an organisation owns to create value for the firm. The circular economy has restored the role of intellectual capital, with external - or relational - capital as the most influenced (Minoja and Romano, 2021). Because of that, the focus of this thesis is on external capital, rather than structural capital or human capital.

External capital also denominated as relational capital is established as the codes, behavioural rules, values and objectives in common between suppliers and customers. External capital related to the external stakeholders' network -consisted on suppliers and customers-, takes into account customers' loyalty, satisfaction, and social responsibility, among others (De Angelis, Howard and Miemczyk, 2017). This is achieved by the alignment of the organisational culture and vision, and as a result from the integration and collaboration between the agents implied (Roos, 2014).

Environmental knowledge management in organisations and learning processes are elements that can help in the transition towards sustainable and circular business models through awareness raising and education in organisations, with an emphasis on supplier and customer relationships. External capital is a crucial factor for organisations and helps build remarkable capabilities for the entire supply chain (Yu and Huo, 2019; Wu, Huo, Yu and Zhang, 2020).

Through external capital, organisations can create competitive advantages by cooperating, accessing, utilising and acquiring resources in their supply chains (Wu *et al.*, 2020). Supply chain relational or external capital can be categorised as customer relational capital and supplier relational capital (Yu and Huo 2019). Supply chain relationships and interactions drive improved environmental collaboration between buyers and suppliers (Woo, Kim. Chung and Rho, 2016).

Manufacturing companies should be more concerned about how to minimise environmental damage by implementing circularity in supply chains, stimulating their innovation, efficiency and cooperation between stakeholders such as suppliers and customers (Wu *et al.*, 2020).

2.3. Circular supply chains

The supply chain is composed of actors that are essential in the implementation of the circular economy to promote circular thinking in organisations and rethink the production system, achieving greener and more efficient processes (Geissdoerfer *et al.*, 2017). The knowledge-based approach, involving partnership structures with stakeholders such as suppliers and customers, also includes the renewal of traditional structures with organisational innovations and processes (Grant, 1996), which is needed to implement circularity in organisations. The basis of this approach could help to understand the transition towards circular economies and circular supply chains that break with linear and traditional models.

The importance of introducing sustainability into firms' supply chains is key to implement circular practices. The circular supply chain expands the number of actors implicated, as it involves new relationships and includes the return of products by customers to any agent implied in the value chain of the production system in the same or different industry (Farooque, Zhang, Thürer, Qu, Huisingh, 2019). The implementation of the circular economy requires the acceptance of all the actors in the supply chain (Muñoz-Torrres, Fernández-Izquierdo, Rivera-Lirio, Ferrero-Ferrero, Escrig-Olmedo, 2018).

The aim of the circularity is to achieve waste reduction and return resources to the production cycle (Genovese, Azquaye, Figueroa, Koh, 2017). Closed-loop supply chains involve the take-back of products at the end of their end-of-life, following circular economy principles. Those products that have been used by customers are taken back and returned to the original manufacturer for re-use. These supply chains involve repair, reuse, remanufacturing, recycling and reconditioning (González-Sánchez, Settembre-Blundo, Ferrari and García-Muiña, 2020).

Coordination and cooperation with suppliers are crucial to supply restorative, recoverable and regenerative raw materials with less negative environmental impacts. Thus, the choice of suppliers and the purchasing behaviour of consumers are the main aspects to consider.

Network coordination depends on the partnerships between downstream and upstream firms in the whole supply chain. Those suppliers that follow both social and environmental standards by the use of reverse and green logistics, can become leaders in environmental management and waste management (Zeng, Chen, Xiao and Zhou, 2017). Negative environmental effects can be minimised by organisations in the different processes. In the supply chain management exists two fundamental pillars: 1) supplier development with sustainable principles, according to current supplier performance improvement, and 2) sustainable election, regarding to the selection process (Masoumi, Kazemi and Abdul-Rashid, 2019). Become supply chain 'greener' relies on sustain environmental and social suppliers' issues. From an environmental point of view, reverse logistics play a key role towards waste reduction and the way in which waste is treated

(Farooque *et al.,* 2019). Cost reduction can be achieved by economies of scale and a better use of resources (Govindan, Mina and Alavi, 2020).

The change in management approach, economic constraints and the lack of knowledge are the main issues in the supplier integration for circular business models. Furthermore, other key aspect is related to stakeholders environmental awareness towards the circular principles implementation (Mangla, Luthra, Mishra, Singh, Rana, Dora and Dwivedi, 2018).

On their behalf, customers role in circular economy is completely different in comparison with the linear economy principles. It supposes consumers transition from being the last link in the supply chain, as a passive figure limited to product purchase, to an active figure participating in the recycling and recovery of products (Borrello, Caracciolo, Lombardi, Pascucci and Cembalo, 2017). This implies a collaborative consumption model that would improve the interaction between customers, suppliers and retailers (Mangla *et al.,* 2018). Changes in consumer behaviour is demanded by this transition in the supply chain, which can be achieved through awareness campaigns and education towards sustainability (Farooque *et al.,* 2019). Circular economy principles affect to customers' elections for products less harmful to the environment, following new consumption patterns and sustainable consumption (Taghikhah, Voinov and Shukla, 2019). Customers' satisfaction and loyalty development is essential to implement circular practices in the supply chain, which improves environmental and economic performance, by means of cooperation and collaboration (Kazancoglu, Kazancoglu and Sagnak, 2018). Masoumi *et al.,* (2019) argue that consumers' behaviours also can affect to change organisations' environmental management. In addition, product designing and reward programs and monetary compensations are fundamental to influence customers behaviours by means of facilitating collecting process of products and waste (Borrello *et al.,* 2017).

2.4. Circular practices applied in the food waste management

Food waste occurs in the last stages of the food value chain: distribution and consumption (Parfitt, Barthel, Macnaughton, 2010). Large amounts of food waste are disposed in landfills, emitting greenhouse gasses, which is harmful for the environment and human health. Food waste management is the use of food products that are recovered for human consumption, industrial uses, animal feed or to achieve environmental benefits (Närvänen, Mattila and Mesiranta, 2021).

In linear food systems, food waste is generated and disposed with a very limited level of recovery. Therefore, the application of circularity and sustainability in the food system is key to reduce food waste. Achieving this is relevant both from the point of view of economic efficiency and the social-ethical standards. Interest has been intensified by the need to achieve the Sustainable Development Goals (SDGs) that would improve food security and sustainability (Santeramo, 2021).

Food waste management requires the implication of all the agents involved in every level of the supply chain. Circular supply chain management includes all supply chain functions to exercise a greater control over all stages or processes, increasing the efficiency, with a greater cost savings and higher levels of quality and food safety (Närvänen *et al.*, 2021).

The benefit of reducing food waste from a circular perspective has environmental, economic and social impacts. At the environmental level, food waste is considered a major contributor to climate change and greenhouse gas emissions, and a major consumer of energy or materials (Närvänen *et al.*, 2021). From an economic point of view, circular waste management reduces costs which it results in lower food prices (Despoudi, Bucatariu, Otles and Kartal, 2021). At the societal level, reducing food waste by utilising unwanted food is beneficial in alleviating worldwide hunger (Chauhan, Debnath and Singh, 2018).

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ARTICLE I

BUILDING EXPLOITATION ROUTINES IN THE CIRCULAR SUPPLY CHAIN TO OBTAIN RADICAL INNOVATIONS

ARTICLE I. BUILDING EXPLOITATION ROUTINES IN THE CIRCULAR SUPPLY CHAIN TO OBTAIN RADICAL INNOVATIONS

The first article consists of a model analysis about the absorptive capacity theory, focus on the exploitation routines and how they play a key role in the incorporation of circular economy management in the supply chains. Firstly, is conducted a circular supply chain management conceptualization and it is pointed the relevant of absorptive capacity. Secondly, two hypotheses are exposed, related to how new and smart technologies can affect to routines associated to new production needs adaptation towards circularity; and how circular economy customers' knowledge can influence in new commercial needs. Thirdly, is used the PITEC panel-type database for the model analysis. Results show the effect of exploitation routines and radical innovations in Spanish technology companies.

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Article

Building Exploitation Routines in the Circular Supply Chain to Obtain Radical Innovations

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Abstract: The adaptation of the supply chain makes it an effective tool in the management of a circular economy, as it allows aspects of sustainability and regeneration to be incorporated into production. However, empirical evidence is still insufficient. In addition, the use of absorptive capacity theory provides a convenient context model that is adapted to the knowledge management required for the application of circularity principles. To study in depth the functioning of the circular supply chain, we use the dimension of exploitation of absorptive capacity, distinguishing between routines that allow adaptation to new production needs (technological knowledge) and new commercial needs (market knowledge). The empirical study was conducted on a sample of 9612 companies, divided into three levels of technology intensity manufacturing, from the PITEC panel using multivariate models. The results show that the operating routines associated with the use of production and logistics technologies developed in a circular fashion favor the development of new products. Similarly, a bidirectional knowledge flow is necessary. The first flow is toward the company with practices that allow a better understanding of the customer and their needs in the framework of the circular economy. The second flow would be toward customers, who need to be informed and educated through various marketing and communication activities to adapt their behavior to the principles of circularity.

Keywords: circular supply chain; circular economy; smart technologies; customers; absorptive capacity; exploitation dimension; radical innovation

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1. Introduction

To achieve long-term economic growth, it is necessary to rethink the production system in order to achieve more ecological and efficient production processes that are profitable for organizations through understanding industry by intention and design with a restorative and regenerative approach to environmental performance or social-welfare impact [1,2].

The application of sustainability principles to the supply chain implies a new perspective on supply-chain management, from the sourcing and use of raw materials to after-sale service [3] to considering green innovation aspects [2]. Sustainable supply chain management is about total costs, including those beyond economic issues. These include mainly environmental or social costs, such as those resulting from emissions in production and transport, or costs resulting from damage to the health of workers or customers.

The circular economy is a further step on the road to more sustainable supply chains. Circular economy (CE) proposes a break with the previous linear system through the development of continuous economies of scale to meet growing demand for new products.

Applying the principles of circularity makes it possible to obtain economic benefits, minimize environmental impacts, and preserve finite resources [4]. On one hand, they reduce the consumption of resources and products; on the other hand, they broaden and deepen the relationships between the various stakeholders.

Regarding changes in operations, circular supply chains (CSCs) allow both a reduction in waste and less consumption of waste by incorporating the products already used as raw materials [5]. The capacity for innovation must permeate the company's entire value chain to minimize or eliminate the programmed obsolescence of products, employ remanufacturing techniques, optimize the production system to reduce the resources used, or manage current resources for future reuse [6,7]. This requires a new supply chain accompanied by the application of circularity in other areas, such as product design, production, or customer services [8].

"Although circular innovation processes seem to differ in their complexity, detailed knowledge about the micro-level innovation processes is lacking" [9] (p. 3). The application of the principles of circularity requires a transformation toward knowledge-based companies [10–12] that consider knowledge to be a fundamental asset and the basis for the development of their strategy; for instance, by using knowledge-based methods to collect, analyze, and configure data that allow the development of deliveries dynamically scheduled [13]. Therefore, companies need to supplement their learning with external knowledge, as they are not able to develop internally all the technological and market capabilities they need to deal with these changes [14–16].

In this sense, ensuring that a company maintains its competitive advantages depends largely on the speed at which it can absorb, integrate, and apply externally generated knowledge [17]. Traditionally, the set of routines to absorptive capacity has been divided into two groups, potential absorptive capacity (PACAP) and realized absorptive capacity (RACAP), according to their relationship with the acquisition of new knowledge and its assimilation or according to the treatment of this knowledge for its application to the productive system and its incorporation into productive innovations [18]. Therefore, it responds to an adaptive perspective that implies the need for change for the correct running of the process in the short term. "Organizations with a strong realized absorptive capacity will be able to transform a greater proportion of the knowledge acquired and more of this transformed knowledge will be applied to their product development, thus generating more innovation results" [19] (p. 322).

The circular economy implies a new paradigm in the productive system and in the capacity of organizations to relate to each other. The exploitation dimension of absorptive capacity needs special attention. Thus, it can respond to the commercial needs that arise in the market after the incorporation of new knowledge both in the production system and in the offer of new products or services [20]. These routines have to be in line with the organization's dominant innovation strategy [21]. To this end, before incorporating the new circular knowledge into the production and logistics system, it is transformed by considering its adaptation in the incorporation into the organizational memory [18,22]. Nevertheless, the study of this phase requires a greater effort, since the literature provides different interpretations about the concrete routines that constitute it.

Considering the direct relationship of operating routines with the market both at the production level and in terms of product development [23], we propose the study of the relationship between exploitation routines and the obtaining of radical innovations, since this type of innovation allows an adequate change to the novelties of the environment.

Consequently, achieving proper functioning of the circular supply chain is fundamental to the successful implementation of CE. Although there is a clear interest in the understanding of the circular supply chain, there is still a gap in establishing the capabilities and knowledge to implement circularity criteria in supply operations.

To fill this gap, in the study of the exploitation dimension of this new knowledge, we will distinguish between its exploration and adaptation to the needs of the organization (technological knowledge) and its application and exploitation for commercial purposes, and therefore with the aim of obtaining an economic return (market knowledge) [24,25]. Technological capacity should take advantage of information technologies to make it possible, for example, to develop functionalities of digital technologies to track products, components, and materials in order to optimize resources [26] or create collaborative sites or platforms [27]. Process-driven technologies have the potential to have strong positive impacts on operational improvement and on social development outcomes [1]. A recent article concluded that technologies have three fundamental values for the CE: increasing resource efficiency, prolonging product life, and closing the cycle [28].

The circular economy represents a revolution not only in the productive sphere, but also in the social and relational spheres [29]. In this sense, it also implies changes in consumer and user habits [30]. The new circular business models are more service-oriented, rather than oriented to mere possession [8]. Therefore, there is a need for new paradigms of relationships and at different points in the supply process. This involves the commitment of the various actors involved [31]. "Multi-echelon supply chains involve the flow of products between different actors comprising of manufacturers, distributors, retailers and customers" [30] (p. 4). Of all these actors, the new relationships established with clients in the circular paradigm require further conceptual and empirical research.

It is important that the complex environmental information needs simplification so that clients can understand the principles of circularity and adapt their habits and procedures. Scientific information is not always comprehensible to consumers or clients, so there is a need to work on simplifying such information and on training to guide more sustainable consumption, while providing relevant and understandable information to influence decisions [32].

The manufacturing sector faces high pressure to implement sustainable innovation processes in its supply-chain management [2]. In this paper, we study the effect that exploitation routines associated with technologies and increased customer knowledge and information have on obtaining novel products that have been achieved through radical innovations. To carry on this research, we define the following research questions:

1. Do new and smart technologies related to circular supply chains allow for radical innovations in their exploitation routines?
2. Does greater knowledge of customers in the circular economy allow for radical innovations in their exploitation routines?

Answering these questions would advance the implementation of the circular supply chain using two of its main intangible resources: technological and relational knowledge. The use of absorptive-capacity theory provides a convenient context model rather unexplored in the context of circular economy [9,33].

The data from the PITEC panel (see Spanish National Statistics Institute) were used to test the hypotheses put forward in this research. These data come from Spanish manufacturing companies of different technological levels and sizes. The results show that exploitation routines in a circular context, both in their focus on internal operations and those related to the research of the market, will favor the propensity to develop new products through radical innovations.

The structure of the present work presents a description of the concept of the circular economy and the relevance of absorptive capacity. After these considerations, we will focus on the management of the circular supply chain and on the main variables that make up its exploitation phase. These variables make up the analysis model proposed for the study of obtaining radical innovations. After describing the methodology used, the main results of the variables analysed are presented. Finally, we discuss these results, and the limitations and future lines of research are considered.

2. Theory: Circular-Supply-Chain Management

The linear economy model known as the "*take-make-consume-dispose*" model is the traditional production and consumption system [34]. This linear economy model is based on the cradle-to-grave approach of production and consumption that implies the generation of a huge amount of waste, and it does not fit with the sustainable systems [35]. In contrast to this system, CE is a restorative and regenerative industrial system to decouple the creation of value from the consumption of finite resources [36]. This circular system, based on the principle of material balance, implies that all material flows must be taken into account [22]. These flows are achieved through durable design based on reuse, remanufacture, restoration and recycling [37]. CE promotes environmentally sound and sustainable use of resources for a greener economy for the benefit of current and future generations [38–41].

According to [42] (p. 373), "A true circular economy must demonstrate new economic system concepts of production and consumption" becoming, in this way, an integrative endeavor at the crossroads of economic, social, and environmental dimensions [36]. Consequently, "CE requires that both producers and consumers become active participants in the recycling and reuse of products" [40] (p. 27). This is a new perspective that requires new theoretical and empirical evidence.

Several environmental issues are gaining attention in order to achieve green-supply-chain innovation [2]. The circular economy requires a deep reform of the whole system to adapt a sustainable development strategy. With regard to corporate environmental management in the circular economy, companies integrate practices aimed at lowering environmental impact with corporate strategies and policies in their search for energy efficiency and reduction of waste flows [43].

Adapting the supply chain makes it a mechanism for supporting the effective operation of a circular economy [44]. A circular supply chain is a closed system that takes into consideration the environment as a part of the system: the waste, the assimilative capacity, and recycling [45]. "The circular value chain is built on the principle of ensuring that all intermediary outputs (physical, energy, informational, relational etc.) that have no further use in the value creating activities of the firm are provided as input to other value chains external to the firm" [46] (p. 254). Through proper management of the upstream and downstream relationships with suppliers and customers that occur in the circular supply chain, it is possible to achieve greater value at lower cost [47].

The importance of the supply chain in the functioning of the circular economy has generated significant interest in the literature to establish the keys to its management (Table 1). Circular-supply-chain management (CSCM) brings into the supply chain aspects of sustainability such as regenerative design, reverse logistic, green supply chain, closed-loop supply chain, design for circularity, and cradle-to-cradle approach [31]. Consequently, CSCM implies enlarging the period of time that materials are kept in use, through increasing the number of consecutive cycles of remanufacturing, refurbishing, repair, and recycling; or prolonging product durability [45].

Although there is a clear interest in the study of the circular economy, this research focuses mainly on the conceptualization of the circular economy or its application in a productive environment [48]. There is a lack of theoretical basis and scientific guidance from the perspective of business management or social aspects [49]. In addition, knowledge management is essential in the implementation of supply chains [50], taking into account the production and consumption processes [43,51].

To fill this gap, this paper proposes a model framed in the dimension of absorptive capacity more associated with production and the market. In the exploitation dimension, we study routines that involve technological change associated with production and with the establishment of procedures to increase customer understanding and education. This coincides with the need to develop advanced technology transfer and monitoring on changing market needs for the adoption of the circular economy [52,53]. Smart technologies will make it easier for practitioners to carry out their circular production activities and, at the same time, help to deliver products adapted to their standards to end users [53]. Building this technological framework is not an easy task and involves a significant amount of research of the needs and the challenges of the new supply-chain distribution [13]. This paper aims to contribute to this by relating some of the technologies used in circular distribution and the achievement of innovations.

Collaborative networks, based on value-chain cooperation, enable materials to circulate in a closed loop [54], allowing companies to receive benefits from supplies and customers' support for research, product design, marketing, supply routes, and production processes. There is a growing need for inter- and intra-organizational connectedness with more trust and greater transparency in information flows [55]. Consequently, both suppliers and customers need to be actively involved [40].

The need for a quick response from the industry to the customer according to the market demands for a green product [2] requires a better understanding of the market. Accessing and managing valuable information has become essential in supply-chain development.

To achieve this commitment, different types of incentives should be developed, ranging from financial incentives to training or technological processes [43].

Considering the importance of absorbing this new knowledge related to the circular economy in the most efficient way, we have used two routines associated with the exploitation dimension of the absorptive capacity. This phase is most directly associated with the market by applying new circular knowledge to new products so that they respond to customer needs [56]. In this way, we can affirm the productive purpose as the central objective of this dimension or phase associated with the exploitation of knowledge [20].

Table 1. Summary of the concept of supply-chain management.

Authors	Denomination	Definition	Main Characteristics	Management Tools	Enhancers (E) or Inhibitors (I)
[57]	Supply-chain management	"Process oriented and customer focused discipline, where material flows are directed from suppliers to customers".	Supply-chain management is a source of competitive advantage for companies. Efficiency, effectiveness, and financial success are the economic-performance criteria of the supply chain.	Life-cycle assessment (LCA); the use of computer-assisted simulators and experiments.	Cleaner and sustainable technologies (E); restriction of strategic options for TBL management, (I); poor attention to social factors (I).
[36]	Sustainable supply-chain management	"Strategic and transparent integration, which seeks to achieve the social, environmental and economic objectives of an organization in the systemic coordination of key interorganizational processes to improve the long-term economic performance of the company and its supply chains".	Sustainability is combined with efficient supply chain management, integrating the concept of green supply-chain management.	Big data and data mining to assess environmental impact. Standardized indicators: GRI. Coordination, collaboration and motivation of the members of the supply chain.	IT as a support to value chain activities (E); multicriteria building models for the creation of sustainable models (E); creation of standardized measurement/evaluation systems (E); companies are not willing to share information related to environmental and social dimensions, unless it is mandatory by law (I); inclusion of the social pillar (I).
[58]	Circular supply-chain management	The circular supply chain promotes the transformation from a linear to a circular model of product flow. Customers can return the product, or what is left of it, to any actor in the value chain of the production system.	Reduction of waste production and achieving self-sustaining production systems in which materials are returned to the production cycle.	Reverse logistics; industrial symbiosis: incentives, administrative control and coordination); and circular business models. IT as facilitating tools.	Promote collaboration between internal and external stakeholders (E); new IT for management and production change (E); legislation to regulate waste management, and sanctions (E); aid to promote the use of renewable energies (E); lack of economic benefits (I); lack of environmental education and changes in behavior (I).

Source: Own elaboration based on other studies.

3. Hypotheses and Method of Analysis

3.1. Hypotheses

3.1.1. New and Smart Technologies for Manufacturing, Logistics, and Distribution

The main role of new technologies applied to the circular economy focuses on making the production, logistics, and flows required by the circularization of the system more efficient [59]. The adaptation of the technology to the circular system has been based on three main factors: (1) the production, for example in the recycling or disposal of waste [60]; (2) the product, for example improving the design or monitoring and enhancing renovation of the product; and (3) the stakeholders, for example attracting target customers [28].

In this line, the application of new and intelligent technology allows modification of the production system to make it more flexible and efficient. Furthermore, smart technology can reduce the negative impacts that this system has on the environment by raising the use ratio of raw materials to minimize waste [49]. Finally, it allows the incorporation of innovations in final products, achieving new products [61,62]. It is worth highlighting the effort made by the company to integrate different processes and technologies that allow operations to be reconfigured from a consideration of circularity according to the needs of the markets, and acquire information on new market trends [63,64].

The circular supply chain is enabled by the implementation of Industry 4.0 technologies that introduce new opportunities for the traditional approach in manufacturing companies. Industry 4.0 increases and improves the effectiveness and efficiency of production processes. There are technologies in Industry 4.0 that enable the application of circularity in the supply chain: Internet of Things, blockchain technology, big-data analytics, cloud technologies, or artificial intelligence [13,53,65]. The benefits of these technologies in the implementation of circularity in supply chains include the tracking of suppliers and customers along the logistics chain and providing real-time access to relevant information [55,65]. The application of data mining related technologies reduces the risk of having underutilized data and not obtaining real-time business information [55].

Consequently, we propose the first hypothesis:

Hypothesis 1. *In the context of circular-supply-chain management (CSCM), exploitation routines related to new and smart technologies for manufacturing, logistics, and distribution have a direct and positive effect on the radical innovation.*

3.1.2. Customers

Customers play a key role in the closed-loop chains, because it is indispensable to their support of the successful implementation of the circular principles [66]. The development of closed-loop material flows will significantly change the potential outputs of the consumption system [67].

Supply chains are changing customer behavior toward encouraging environmental options, but it is necessary that this actor have awareness of the advantages of green products to increase their willingness to pay for these products [49,68]. This stakeholder is a focal actor in the circular economy, sharing products with other actors and their activities to extend the use of their products and choosing sustainable packaging [69]. Customers perceive products from the circular economy as more efficient in the use of energy and resources, and with higher economic, social, and environmental values and even higher quality [70]. Previous consumer experience, environmental awareness, practical or utilitarian concerns, and product knowledge are the four factors that influence the customer's choice of recycled and remanufactured products [66].

It is important to analyze the real costs associated with the implementation of the CE [36]. Costs of changes related to circularity are also related to maintaining deeper relations and communications with the key stakeholders [71]. In this context, dialogue and development of a transparent risk-communication strategy are essential [72].

Customers' behavior affects the adequate commercial application of the circularity criteria. The main impediment of a circular-economy transition is customer acceptance and their lack of interest and awareness [73]. Customers have limited means to understand the extent to which their consumption contributes to environmental degradation, due mainly to the temporal and geographical separation of production and consumption [32]. They need more information about the products (i.e., the origin, the traceability, components, and the perceived quality) [65]. With an action-learning approach, companies added an anticipatory dimension to the process, allowing preferred futures to evolve continuously with stakeholder participation [53,72,74]. An adequate design of marketing activities would make it possible to train and inform customers about the application of the circular economy to the distribution, consumption, and return of products.

Similarly, there is a need for greater knowledge about market demands related to sustainability through dialogue and a transparent communication strategy [53]. To respond to these requests, exploitation routines can be established in the supply chain to inform, train, and get to know the customer. By applying information and measurement systems in the circular supply chain, we manage to establish procedures that protect the value of the materials used in the manufacture of the products commercialized [75]. Market studies will allow a better knowledge of the customer in order to adjust the products to their new needs related to sustainability and the recovery of the already-used products. Similarly, through marketing activities, the company can make its products known and encourage customers to behave in a way that is favorable to sustainability. The predictive analysis provided by big data is very useful for understanding future market trends, and therefore companies can anticipate these trends and increase the success of their products [31,76]. This capacity is of great value in a novel field such as that of the interpretation of the clients of the implications of the circular economy.

Based on the above arguments, our second hypothesis focuses on market-related exploitation routines:

Hypothesis 2. *In the context of circular-supply-chain Management (CSCM), exploitation routines related to market research and related marketing activities have a direct and positive effect on the radical innovation.*

In Figure 1, we have shown the analysis model that represents the relations proposed between the two exploitation routines, previously justified and radical innovation, due to its relevance to innovative performance. These relationships are represented in Hypotheses 1 and 2.

3.2. Method of Analysis

In our research, we used the PITEC panel-type database of the Spanish Foundation for Science and Technology (FECYT), the National Institute of Statistics (INE), and the Cotec Foundation. This database provides information on aspects related to the innovative activities of 12,838 Spanish technology companies.

By screening the companies that did not have the necessary data for our studies, we divided the 9612 companies in our sample into three levels of technology intensity, following OECD criteria.

The multivariate model was used, as it is a statistical tool that allows the use of multiple variables to predict an outcome. In our paper, the variables offered by PITEC have been studied, and with the theoretical support of the literature review carried out, the indicators of the survey with the highest content validity [77] were deductively selected to guarantee the suitability of the responses given by the participants in relation to the construct exploitation routines of absorptive capacity.

Considering the above, there is a time difference between the performance of a certain innovative activity and the results obtained from it. To give a statistical solution, we incorporated a time lag following the study of [78]. Therefore, we differentiated between two years of dependent data (exploitation routines in 2010) and the independent variable (radical innovations in 2012).

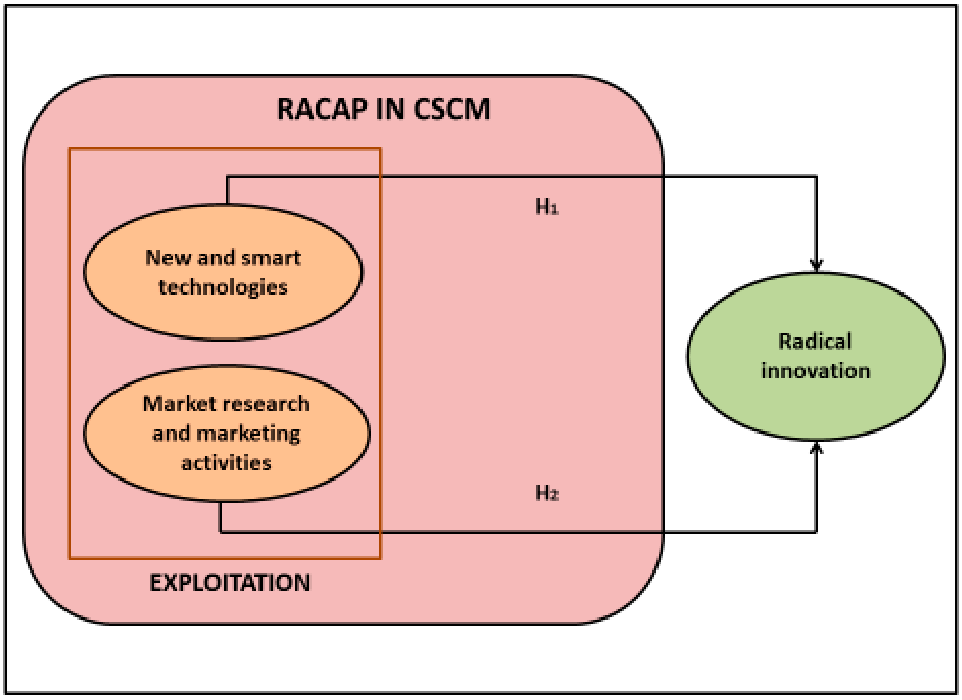

Figure 1. Model of analysis.

3.2.1. Independent Variable: Exploitation Routines

For the exploitation phase, we have incorporated the indicators that allow us to collect the routines that were justified in our review of relevant previously published papers. On one hand, we considered the routines related to production operations associated with production, logistics, and support activities; on the other hand, the routines associated with the market allowed us to establish flows of knowledge with clients in both directions. These variables satisfied theoretical validity criteria considering previous research [61,79,80]. The results of the factor analyses of the operating phases are included in Table 2.

Table 2. Exploitation phase: measurement indicators.

Independent Variable Exploitation Phase: Incorporation and Application of Knowledge in Operations		
Indicators (PITEC)		
Dichotomous Variable		
Operations: - Procedures associated with production, logistics, and support activities Market: - Market studies, promotion, and communication		
KMO	0.775	
Bartlett's test	Sig: 0.000	
% Acumm.	83.06	
Reliability (Cronbach Alfa)	0.	N.A.
Support activities	0.871	−0.019
Other preparations	0.994	0.670
Market research	0.144	0.848

Being the absorptive dimension that maintains a more direct relationship with the market and its customers [23], an adequate selection of the activities or routines to be carried out in this phase would improve the radical innovations necessary for the correct application of the sustainability criteria. They are a consequence of the need to give novel solutions through them to the new problems or market requests associated with circularity.

Within this phase, it is worth highlighting the company's effort to integrate technologies that allow manufacturing, logistics, and distribution operations to be reconfigured according to the needs of the markets. We also considered information on new applications and the recovery of the product once used.

Through this application, it is possible to achieve greater flexibility and greater production capacity, the obtaining of improved or new sustainable products, and the reduction of direct costs or those derived from environmental impact [61,62]. The routines that provide contact with the market improve access to valuable knowledge from customers and therefore, adjust to their demands [81].

The different multivariate models will be presented, including first the control variables, and then the predictor variables will be considered individually. All this will be done once it has been verified in all cases that the representative variables of the different phases of the absorptive capacity maintain significant relations with the result variable through univariate logistic analyses.

3.2.2. Dependent Variable: Radical Innovation

We identify innovative performance with the incorporation of new ideas to the production of improved products or services [80]. This improvement reaches different degrees, from the consideration of more sustainable products or new uses of them [69]. Customers value it as a novelty when it provides new or improved utilities. In a circular-operation framework, these new functions will be related to additional uses, less packaging elements, longer life or return facilities; for this, an adequate exploitation of technological knowledge is required [82].

Our database defines the radical innovation considering this novelty in the products offered to the market.

3.2.3. Control Variables: Size, Age, and Sector

We used three control variables considering the age, size, and sector of the company. To calculate the age of the company, the year it was created was considered. The size was measured using the number of employees. In the case of the sector, the level of technological development was considered.

The size conditions the capacity to develop new innovations that the company will apply to the products [83]. The age of the organization may bring experience to the organization, but may also mean an increase in organizational inertia that makes innovative performance difficult. Finally, the industry of membership must be considered, as it has characteristics that affect the development of innovations.

4. Results

We present the different multivariate models, including first the control variables; subsequently, the predictor variables were considered individually. All this was done once it was verified in all cases that the representative variables of the different phases of the absorptive capacity maintained significant relations with the result variable through the univariate logistic analysis. The correlations matrix is shown in Appendix A.

4.1. Control Variables

For the variable introduction of radical innovations in the market, the results of the control variables are shown in Table 3. Significant relations are marked in bold.

The model with the control variables passed the omnibus tests, which allowed us to conclude the significance of the relationships and, therefore, the need to incorporate the control variables when explaining the introduction of radical product innovations.

However, the precision of this occasion was lower, presenting figures that were also modest in terms of their explanatory capacity.

Table 3. Control variables and introduction of radical innovations in the market. Significant relations are marked in bold

Model Summary								
Variable Result	**Omnibus Test Coefficients**			**−2 Log of Plausibility (Deviation)**	**Nagelkerke Square R**		**% Success Rate**	
	Chi Square	**gl**	**Sig. (Bilateral)**					
Radical innovations	398.641864	23	0.000	9453.715251	6.3%		79.1%	
	B	**Standard error**	**Wald**	**gl**	**Sig.**	**Exp(B)**	**95% CI for EXP(B)**	
							Lower	**Upper**
Age (0)			2.946	2	0.229			
Age (1)	−0.082	0.212	0.150	1	0.699	0.921	0.608	1,395
Age (2)	−0.224	0.203	1.216	1	0.270	0.799	0.537	1.190
Sector In Tech (0)			13.976	3	0.003			
Sector In Tech (1)	0.854	0.343	6.196	1	**0.013**	**2.349**	**1.199**	**4.602**
Sector In Tech (2)	−0.658	0.503	1.712	1	0.191	0.518	0.193	1.388
Sector In Tec (3)	0.632	0.281	5.058	1	**0.025**	**1.881**	**1.085**	**3.261**
Size (0)			7.679	3	0.000			
Size (1)	0.872	0.167	27.217	1	**0.000**	**2.392**	**1.724**	**3.320**
Size (2)	1.312	0.169	60.307	1	**0.000**	**3.715**	**2.668**	**5.174**
Size (3)	1.414	0.186	57.731	1	**0.000**	**4.114**	**2.856**	**5.925**
Sector In Tech (0) * Age (0)			21.001	6	0.002			
Sector In Tech (1) * Age (1)	−0.354	0.323	1.202	1	0.273	0.702	0.373	1.322
Sector In Tech (1) * Age (2)	−0.690	0.329	4.411	1	**0.036**	**0.502**	**0.263**	**0.955**
Sector In Tech (2) * Age (1)	−0.516	0.425	1.472	1	0.225	0.597	0.260	1.374
Sector In Tech (2) * Age (2)	−0.414	0.409	1.027	1	0.311	0.661	0.296	1.473
Sector In Tech (3) * Age (1)	−0.942	0.256	13.567	1	**0.000**	**0.390**	**0.236**	**0.643**
Sector In Tech (3) * Age (2)	−0.706	0.245	8.280	1	**0.004**	**0.494**	**0.305**	**0.798**
Sector In Tech (0) * Size (0)			7.022	9	0.635			
Sector In Tech (1) * Size (1)	−0.064	0.267	0.058	1	0.810	0.938	0.556	1.582
Sector In Tech (1) * Size (2)	−0.202	0.288	0.490	1	0.484	0.817	0.465	1.438
Sector In Tech (1) * Size (3)	−0.335	0.342	0.961	1	0.327	0.715	0.366	1.398
Sector In Tech (2) * Size (1)	0.329	0.392	0.708	1	0.400	1.390	0.645	2.995
Sector In Tech (2) * Size (2)	0.189	0.392	0.232	1	0.630	1.208	0.560	2.606
Sector In Tech (2) * Size (3)	0.045	0.398	0.013	1	0.910	1.046	0.480	2.281
Sector In Tech (3) * Size (1)	−0.235	0.218	1.168	1	0.280	0.790	0.516	1.211
Sector In Tech (3) * Size (2)	−0.379	0.220	2.968	1	**0.085**	**0.685**	**0.445**	**1.054**
Sector In Tech (3) * Size (3)	−0.465	0.236	3.893	1	**0.048**	**0.628**	**0.396**	**0.997**
Constant	−1.921	0.238	64.928	1	0.000	0.147		

* Joint effect of the variables.

Size affected significantly and positively, as in the previous case, while the technological intensity of the sector affected two of three categories in the expected sense; that is, the higher technological intensity increased the probability of introducing radical innovations into the market (except in the medium-high technological-intensity group). Firms in medium-low technology-intensity sectors doubled the rate of such innovations (Exp (B) = 2.349) in relation to those in low-intensity sectors, and firms in high-technology-intensity sectors almost reached this figure (Exp (B) = 1.881). However, the results made it possible to predict certain effects that derived from the characteristics of the business fabric according to the type of industry.

Finally, the harmful effects of organizational inertia as they age on the potential for developing radical innovations, not only in sectors of high technological intensity but also in those of medium-low intensity, were also apparent. This effect was also observed in large firms, especially in high-technology-intensity sectors. These relationships show that the economic and financial resources of large firms are not so strategic compared to the organizational routines and other assets of smaller firms that are able to compete in technologically demanding industries.

4.2. The Individual Effect of Exploitation Routines and Radical Innovations

Once the effects of the control variables were controlled, we analyzed the direct relationship between the routines of the exploitation dimension in obtaining radical innovations incorporated into the market (Table 4). Significant relations are marked in bold.

Table 4. Exploitation routines and the achievement of radical innovations. Significant relations are marked in bold.

Model Summary						
Variable Result	Omnibus Test Coefficients			−2 Log of Plausibility (Deviation)	Nagelkerke Square R	% Success Rate
	Chi Square	gl	Sig. (Bilateral)			
Radical innovations	981.371	30	0.000	6.344.629	20.7%	74.5%

	B	Standard error	Wald	gl	Sig.	Exp(B)	95% CI for EXP(B)	
							Lower	Superior
Operations exploitation	0.500	0.036	191.631	1	**0.000**	**1.648**	**1.536**	**1.769**
Market exploitation	0.131	0.051	6.692	1	**0.010**	**1.140**	**1.032**	**1.260**
Constant	−1.824	0.263	48.004	1	0.000	0.161		

Discounting the effects of the control variables, a significant increase in the coefficient of determination was observed, which reflected the greater explanatory capacity of the variables representing exploitation capacity. Its accuracy was significantly improved, in accordance with the reduction in the deviation from the complete model and the smaller amplitude of the different confidence intervals of the ROs.

With regard to the predictor variables, the significant and positive natures of the two modes of exploitation capacity were observed. When analyzing the data in Table 4, we can affirm that the Hypotheses 1 and 2 should not be rejected.

5. Discussion

With a lower consumption of raw materials and resources, circular production systems achieve better results in generating fewer negative impacts on the environment [84]. We can consider this production as a new interpretation of sustainability from two basic points of view: (1) the design of processes and products or services, and (2) the relationships through the industrial symbiosis partnership and the customer behavior or the societal acceptance [75,85]. To achieve an efficient functioning of the circular system, we must ensure that the different actors act in a consensual and integrated way that allows the obtaining of different types of synergies, being essential to optimize the flow of knowledge [86]. The strategic responses to these questions are complex and require a new interpretation of the set of elements that interact with each other and with various other elements [74].

The supply chain plays an essential role in the transition to circular business models, as the successful implementation of the circular economy requires the cooperation and acceptance of all parties involved in the chain [87]. One of the difficulties in implementing the circular economy is related to the increase in costs associated with production; for example, the higher energy consumption of a more complex recycling process. Costs will also increase due to the need to maintain deeper relations and communications with the key stakeholders [71].

The contribution of this paper is twofold and includes both theoretical and practical considerations.

5.1. Theoretical Contribution

This paper examined the importance of knowledge management in the implementation of circular supply chains. Organizations with well-managed knowledge flows showed greater efficiency and productivity, which had a positive impact on their ability to innovate and made them more competitive in their industries [88].

For this purpose, we used the absorptive capacity framework, given the importance of technological and market knowledge in the success of this process. Whereas other studies have focused the investigation of its mechanisms in the construction of a sustainable framework on more internal dimensions of absorptive capacity such as transformation, we focused our proposal on the exploitation dimension, given its close relationship with the supply chain and the end-market customer.

5.2. Practical Contribution

From the managerial perspective, the results highlighted the significance of institutionalizing CSCM practices based on knowledge in organizations to improve their innovative performances. Practitioners need guidelines for implementing the principles of circularity in general and concrete proposals for achieving concrete results.

The application of new technologies to the production system allows the development of new functions in order to adapt to the changes that CE represents [26]. We analyzed new and smart technologies that favor both the operational processes for logistics, design, and monitoring of products, as well as the optimization of recycling and energy consumption in the management of supplies.

Furthermore, developing a relational capacity is also essential. In an area of circularity, the map of relationships widens and deepens. These relationships are useful since greater flows of knowledge and resources are achieved, as well as higher levels of commitment. In this way, customers are incorporated into internal activities [42].

Most of the organizations overlooked the social aspect in their sustainability policies [88]. Therefore, this study proposes tools related to the improvement of communication and education to optimize knowledge flows with customers. We propose that a bidirectional knowledge flow is necessary. On one hand, organizations had to inform and educate customers so that they are committed and modify their actions to develop consumption based on the principles of circularity. In synthesis, our results support the importance of the use of both new and smart technologies in exploiting external knowledge for radical innovations. Market research and the use of marketing tools that allow companies to get closer to customers and influence their circular behavior [36] provide valuable external knowledge that favors the application of product innovations.

5.3. Limitation and Future Recommendation

Some aspects of methodological design were a limitation in this paper. Although PITEC is a database that has been widely used in previous studies on innovation and the circular economy, the use of primary sources of information can enrich the measurement of exploitation capacity. To this end, different types of technology or different types of studies or marketing tools could be studied individually with regard to innovative performance. For instance, "to evaluate software tools that can help with modeling of processes for other supply chain operations" [13] (p. 17). In the routines associated with the market, we can include new retail technologies, associated with the different moments of the purchase [89]. The use of digital tools can help to enable the proper use and recovery of resources, explore new ways to connect with customers, and build fast and low-cost profiles in sales channels [66].

In addition, this article studied the individual and direct relationships of different variables of the exploitation phase in the innovative outcome of the circular economy. In future research, it would be of interest to establish joint relationships between the variables of these phases or with other variables of other phases of the absorptive capacity. Similarly, the mediating or moderating effects of other variables, such as investment in R&D, can be studied.

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Appendix A

Table A1. Correlation matrix.

			1	2	3	4	5	6	7	8	9	10	11
		Pearson correlation	1										
1.	Size	Sig. (bilateral)											
		N	9612										
		Pearson correlation	−0.111 **	1									
2.	Age	Sig. (bilateral)	0.000										
		N	9612	9612									
		Pearson correlation	0.084 **	−0.016	1								
		Sig. (bilateral)	0.000	0.120									
3.	Sector	N	9612	9612	9612								
		Sig. (bilateral)	0.000	0.000	0.001	0.000	0.000	0.000	0.000				
		N	9612	9612	9612	9612	9612	9612	9612	9612			
4.		Pearson correlation	0.103 **	−0.074 **	−0.076 **	0.158 **	0.107 **	0.118 **	0.276 **	0.129 **	1		
	Exploitation	Sig. (bilateral)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
	operations	N	9612	9612	9612	9612	9612	9612	9612	9612	9612		
5.		Pearson correlation	0.157 **	−0.017	0.048 **	0.033 **	0.068 **	0.324 **	0.056 **	0.121 **	0.000	1	
	Exploitation	Sig. (bilateral)	0.000	0.101	0.000	0.003	0.000	0.000	0.000	0.000	1.000		
	market	N	9612	9612	9612	9612	9612	9612	9612	9612	9612	9612	
		Pearson correlation	0.099 **	−0.027 **	−0.084 **	0.277 **	0.222 **	0.257 **	0.152 **	0.077 **	0.026 **	0.264 **	1
6.	Radical	Sig. (bilateral)	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	
	innovation	N	9612	9612	9612	9612	9612	9612	9612	9612	9612	9612	9612

** correlation is significant at 0.01 level (2 tails).

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ARTICLE II

NEW CIRCULAR NETWORKS IN RESILIENT SUPPLY CHAINS: AN EXTERNAL CAPITAL PERSPECTIVE

ARTICLE II. NEW CIRCULAR NETWORKS IN RESILIENT SUPPLY CHAINS: AN EXTERNAL CAPITAL PERSPECTIVE

The second article is related to the application of circular economy to ensure resilience routines in the supply chains. A new customer-supplier relationships following the capital-based view theory towards circular principles implementation is focus on collaboration and cooperation is required. Firstly, is carried out a systematic literature review about the main concepts -circular economy, circular supply chains and intellectual capital- with a resilience approach. Secondly, it is developed a conceptual-exploratory model with the linkage between external capital and circularity in supply chains: supply chain intelligence integration, the use of Industry 4.0 in logistic and transportation. Regarding to suppliers, consider ethical codes and tools multicriteria, the assistance, an active participation and reward mechanisms. Finally, referring to customers warranty policies, additional services and new contract service-oriented, environmental education, rewards and discounts are required.

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Article

New Circular Networks in Resilient Supply Chains: An External Capital Perspective

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Abstract: The pandemic caused by COVID-19 has had an impact on the relationships established between different actors in organisations. To deal with these changes, it is necessary to develop a resilience capacity that allows for the establishment of different patterns of relationships through a new management model. The application of circularity principles implies a radical change in stakeholder relations, breaking with the "end-of-life" concept existing in linear economies. Furthermore, circular economy can ensure resilience in supply chains, and it can be considered as a tool in uncertain environments. Therefore, the objective of this study is to analyse the association between the customer–supplier relationships with circular supply chains based on the intellectual capital-based view theory. External capital is a crucial factor for organisations, and it helps with building remarkable capabilities for the whole supply chain due to collaboration and cooperation. This research contributes with a systematic revision of the literature regarding circular supply chains and customer–supplier external capital, providing an exploratory model. Establishing a closer and effective relationship with customers and suppliers supposes a differentiating value and competitive advantages. Actors involved in the supply chain are essential in the implementation of circularity in organisations for reducing waste production and returning resources to the production cycle. Therefore, circular networks related to customers' behaviour, sustainable supplier election and IT tools play a key factor in improving resilience in supply chains.

Keywords: resilient supply chains; external capital; customer–supplier relationship; circular network

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1. Introduction

The COVID-19 pandemic has had an unprecedented impact on the global industry at all levels around the world [1–3]. Effective crisis management is required in order to restore the confidence between socioeconomic actors. However, beyond the consideration of the negative effects of this type of historical crisis, this new scenario can be a source of opportunities for beneficial change. The concept of resilience is incorporated into the management of organisations to guide this change. "Resilience is the capacity of a system to anticipate, adapt, and reorganize itself under conditions of adversity in ways that promote and sustain its successful functioning" [4] (p. 1).

One of the organisational processes most affected by the current health crisis involves activities related to the supply chain that have been affected by severe ruptures and dysfunctions not experienced in previous pandemics [5–12]. This is because this involves a network of stakeholders and a means of distribution involved in the different global processes and activities. Supply managers have had to deal with a variety of problems such as: (1) mobility restrictions and border closures, (2) shortages of raw materials and workforce, (3) the maintenance of social distance, (4) the radical increase in certain demands for both raw materials and final products and (5) the diversion of certain raw materials for the manufacture of products considered to be of greater need to combat COVID-19 [11]. As a result, they have had to adapt quickly to a situation where strategic planning did not anticipate this new scenario. Organisational resilience involves a capacity to adapt to turbulent environments through routines that enable rapid and appropriate responses to change. Thus, the association of resilience and the supply chain has attracted the attention of researchers, although we are still at a basic stage of development.

A resilient supply chain (RSC) enables greater manageability for dealing with disruptions in uncertain business environments, such as the situation caused by COVID-19 [9–12]. The severe impact of the COVID-19 pandemic on supply chains leads us to conclude that it is necessary to establish new patterns of relationships in order to solve scenarios in which social distance and mobility restrictions must be maintained [6,10–14].

One of the factors that is attracting the most attention with regard to supply chain management at this stage of the health crisis is related to the new rules that must regulate relations with the different stakeholders [10,11]. Establishing a new framework for more sustainable relationships with suppliers and customers in the postpandemic period would improve value creation. As an example, the automotive industry has relied on global-scale supply chains based on maximum efficiency and just-in-time parts supply, processes that have been blown apart by COVID-19-related restrictions. With a high dependence on components from China, the industry has to diversify its supply chains in order to reduce the risk of stock shortages. However, in the Spanish automotive sector, a significant number of component suppliers are located in the local area of the manufacturers. Therefore, during this crisis, the occasional component shortage was quickly resolved early in the pandemic.

The crisis recovery plan should be based on flexible production strategies involving external and internal resources and capacities. Therefore, achieving a resilient supply chain requires both logistics and relationship network redesign to reduce vulnerability [15]. This study aims to contribute to the establishment of a framework of relationships that will enable the supply chain to be resilient in the face of crises of global impact. Expanding the number of suppliers to cooperate, finding suppliers in proximity to production locations, establishing tools to facilitate communication and involving customers in the return of used products would all contribute to the adaptation to the new business reality [16].

Although many organisations have prioritised survival over investment in other "non-priority activities" [11], this crisis is an opportunity to consider sustainability as a priority investment in the future as well as a differentiating element. Sustainability is positively related to resilience [17]. The application of sustainability principles to the management and development of the supply chain would make it possible to achieve a more efficient operation with a more engaged ecosystem. It is necessary to incorporate a new framework that regenerates the relationships in the most sustainable way possible. In this way, the application of the principles of circularity would facilitate this transformation [18–20].

The circular economy represents a further step forward in the field of sustainability by breaking with the linear production model with substantial modifications in both operations and relationships [20]. The principles of circularity can provide the supply chain with greater resilience and a more flexible response to future disasters [21]. The functioning of a circular system depends to a high degree on the establishment of well-founded partnerships, mainly with suppliers and customers, which requires the application of a variety of disciplines at different levels [22].

The customer–supplier relationship mechanisms linked with circular economy and supply chains have not been studied enough in the extant literature [23]. To manage this from a resilience perspective, it would be useful to incorporate a theoretical framework to facilitate a developmental model. In this regard, this study is based on the intellectual capital-based view theory (ICV). This theory proposes an efficient management of knowledge through its relationships among external capital, human resources, human capital, organisational design and structural capital. Knowledge management in the supply chain is a topic that is still understudied in the literature, and mainly from a quantitative approach [24]. Recent studies highlight the importance of resilient supply chains according to their intellectual capital [13].

In addition, intellectual capital (IC) enables the development of sustainability by generating synergies between stakeholders through novel combinations of their different utilities [25]. Currently, the number of articles about sustainability and intellectual capital has increased, even coining the term "green intangible capital" [25,26], but there is a gap in the research between circular economy and intellectual capital.

External capital is an intangible asset that focuses on the establishment of superior relationships with stakeholders through the alignment of different interests. These stakeholders' interests include concerns about green problems [26]. Through external capital, intellectual capital literature has addressed the study of these aspects and evaluated their strategic potential. Hence, the integration of circular economy and intellectual capital theoretical frameworks can advance developing sustainable and flexibly functioning relationships in turbulent environments.

A resilient supply chain is crucial to financial and economic survival [9,12,13], highlighting the importance of collaborative relationships with customers and suppliers, which could minimise and mitigate disruptions and the negative impacts of the COVID-19 pandemic on supply chains. Our research aims to contribute to the construction of a CI-based theoretical framework that enables the development of circular networks in a resilient supply chain. Specifically, the research questions to be answered are:

1. How does the circular network enable the development of resilience routines in the supply chain based on the intellectual capital-based view theory?
2. How do circular networks in resilient supply chains support sustainability?

This study aims to contribute theoretically to the foundations of resilient supply chains through a systematic literature review. For this purpose, we follow the following structure. After the introduction, the research methodology is presented. In Section 3, the theoretical framework is elaborated. Firstly, the extant literature about the term intellectual capital is explored related to different models, and its three more accepted categories in the current literature are explained. Secondly, the circular economy and circular supply chains concepts are defined, and they are studied with a resilience perspective. In Section 4, the linkage between intellectual capital, particularly external capital, and circularity in supply chains is exposed in a conceptual model, which is developed in Section 5, with seven propositions highlighting the key role of customer–supplier relationships among supply chains towards implementing more circular practices. Finally, in Section 6, conclusions, contributions, limitations, and future research are exposed.

2. Research Methodology

The method applied in this study is based on exploratory and conceptual research analysing the link between circular supply chains and external capital. The lack of results obtained in the searches for 'circular economy' or 'circular supply chain' and the concept of 'external capital' have highlighted the gaps to fill in this research.

Systematic reviews are used to synthesise findings in a systematic, reproducible and transparent way [27]. Their use in business research is increasing [28]. This type of review is a research method and process in which the data analysed and collected is assessed and identified. The purpose of a systematic review is to detail and recognise pre-established criteria in the literature to answer the research question suggested. In order to reach reliable results to make decisions and draw conclusions. Qualitative systematic reviews compare results from qualitative studies, compiling articles and assessing quality. The strength of this type of analysis is to study whether an effect is repeated or constant across studies and which studies show this [29].

The information has been extracted from the Web of Science database. The literature review was conducted between January 2021 and April 2021. The search protocol defined is as follows: firstly, the terms were selected, and the keywords were combined using the Boolean operators 'AND' and 'OR' in order to refine the information found. The keywords used in the search were: 'circular economy' OR 'circular supply chain' AND 'intellectual capital' AND/OR 'external capital'. Whilst the terms associated were 'suppliers' and 'customers'. Secondly, the results obtained were recorded filtering them by subject and title. Table 1 shows the most researched topics.

Table 1. Most researched topics.

Topics Researched		**Number of Articles**
Circular economy/Circular supply chain	Customer relationship	8
Circular economy/Circular supply chain	Customer behaviour	31
Circular economy/Circular supply chain	Supplier relationship	9
Circular economy/Circular supply chain	Supplier behaviour	7

The total number of articles available for review were 408. The searches were sorted by journal, selecting the articles that had been published in high impact journals (Journal Citation Report, (JCR) Q1–Q2 and Scimago Journal & Country Rank, (SJR) Q1, resulting 122 articles). The main journals are the following: *Business Strategy and the Environment*; *Ecological Economics*; *Environment Development and Sustainability*; *Journal of Cleaner Production*; *Journal of Economics & Management Strategy*; *Journal of Environmental Management*; *Journal of Industrial Ecology*; *Journal of Intellectual Capital*; *Journal of Knowledge Management*; *Production Planning & Control*; *Renewable & Sustainable Energy Reviews*; *Resources, Conservation and Recycling*; *Sustainability Science*; *Sustainable Development* and *Sustainable Production and Consumption*. Then, the searches were sorted by author, date of publication, title and abstract reading, excluding 67 articles. The most relevant papers were selected, gathering a core sample of 55 papers, taking into account the purpose of this analysis. In Figure 1, this review process is represented.

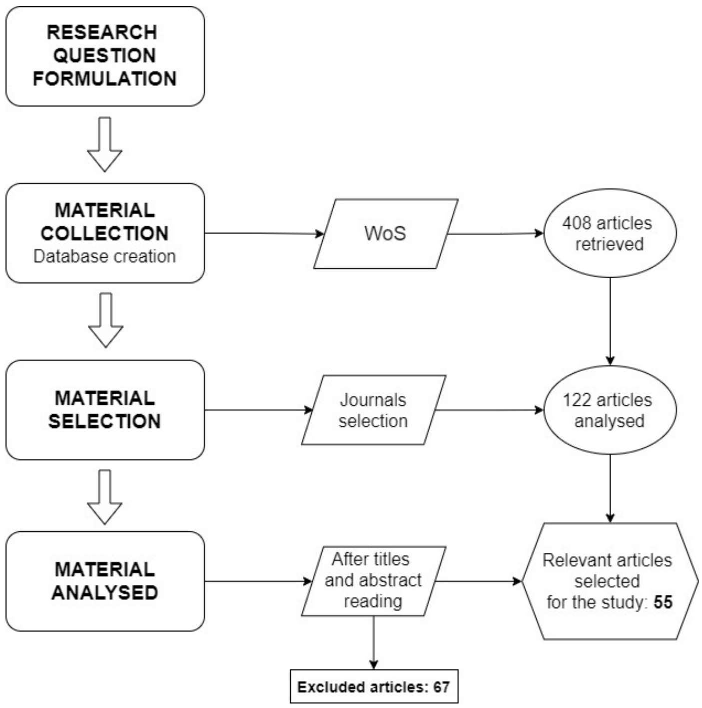

Figure 1. Review process.

Subsequently, once the methodology used in this paper has been explained, the following section will show the theoretical background, conceptualising the main terms studied in this article: resilient supply chain; circular economy and supply chains; and intellectual capital.

3. Theoretical Background

3.1. Resilient Supply Chain

Resilience is the capacity for an enterprise to adapt, reorganise its system and keep surviving and growing when a change is undergoing, whilst disturbance is absorbing [30]. RSC implies "the ability of a supply chain to return to normal operating performance, within an acceptable period, after being disturbed" [31] (p.2). The concept of resilience in supply chains refers to mitigating and anticipating disruptions and disturbances throughout adapted techniques for decreasing vulnerabilities in uncertain environments [30].

Operations in the supply chain are constantly under change and conditions of uncertainty; thus, resilience is a key factor. Supply chains must be prepared to respond to unexpected events [32]. Collaboration, supply chain reengineering, agility, innovation, flexibility, visibility, sharing and trust are the main principles for supply chain resilience [31]. Researchers have argued for the importance of some factors for enhancing resilience in supply chains, highlighting integration, cooperation and communication. The capacity to return more quickly to equilibrium after a period of disturbance is called stability [32]. Visibility is also a crucial element of risk reduction in supply chains.

The complexity in supply chain networks demands more resilience. It plays a critical role in the adaptiveness of networks, their interdependencies, their interactions throughout the whole system and their ability to change its behaviour. Designing resilience, collaboration between suppliers and customers, agility and following a risk management culture are general principles for resilience in supply chains networks [30]. Logistics capabilities, such as low-cost distribution, reliability, delivery speed and responsiveness towards dynamic integration, enables resilience in the supply chain for a competitive advantage. Resilience is a requirement in order to achieve sustainable development, and thus a transition to circular networks [32].

3.2. Circular Economy and Circular Networks

Environments change rapidly, which is why companies depend on their capabilities to reconfigure, integrate and build their internal and external competencies. Organisations must be able to achieve competitive advantages in innovative ways [33]. Based on this theory, in order to implement new circular models, organisations must rely on their dynamic capabilities. This would enable them to make the transition to more sustainable and circular processes and products, reconfiguring the structure and transforming their relationships in closed-loop chains.

Supply chains can be open or closed loop [34]. Open-loop chains imply that third parties recover materials. Closed-loop chains recover products from customers, returning them to the producer for recovering the value and being able to reuse it as a whole or in part. The aim of both chains is to reuse and recover the value of products and resources, maximising their life cycle and preventing waste by incorporating their return over time [35]. Effective implementation of closed loops depends on the involvement and participation of stakeholders in the supply chain, with the alignment of technical, economic and environmental elements. Relationships with suppliers and customers enable adaptation and resilience to changes in the environment [36].

The circular economy is a restorative and regenerative economic model that breaks with the linear economy, replacing the concept of "end-of-life" by seeking to maintain resources and their value for as long as possible. It seeks to reduce the negative effects on the environment by reducing and eliminating waste [37]. This system aims to minimise the emission and leakage of energy by tightening energy and material loops, following the principle of material balance based on recycling, reuse, refurbishment and remanufacturing [38].

Circular supply chains can bring resources back into the production cycle and reduce waste and residues. The reverse supply chain involves an adaptation of circular economy principles to supply chain management, including product design, activities to maximise value creation and product recovery, among others. In this way, damaged products are brought back into operation through the logistics network by means of reconditioning and remanufacturing [39]. Supply chain actors play an essential role in the implementation of the circular economy to promote circular thinking in organisations and rethink the production system, achieving greener and more efficient processes [38]. This circular approach involves expanding the number of partnerships, expanding the number of collaborators and reaching more stable agreements with stakeholders in different industries, mainly suppliers and customers [23]. For this, traditional structures and organisational processes must be renewed with innovations.

3.3. Conceptualising Intellectual Capital

The concept of "intellectual capital" was first introduced by Galbraith in 1969, who defined it as an element that produces value for the organisation. A knowledge-based view concerns strategic choice and competitive advantage, taking into account the organizational structure, the nature of coordination and the theory of innovation, and allowing for the renovation of traditional processes and structures in organisations [40]. Thus, intangible resources and assets enable organisations to create value. Intellectual capital (IC) is often synonymous with intangible assets [41]. In this sense, IC is linked to the theory of resources and capabilities, understood as the set of intangible assets and capabilities that a company possesses to generate value to the company. Capabilities lie in processes, and its competitive advantage is based on a collection of skills, complementary assets and routines that are complicated for competitors to imitate.

Sustained competitive advantage depends on the alternatives of competitors to duplicate an organisation's attributes that imply an advantage [42]. Imperfections in transferability imply that resources are not freely transferable and are not available to everyone, because they are heterogeneous and scarce. Competitors cannot imitate valuable organisational resources, which is called "imperfectly imitability". Organisations seek causal ambiguity between their competitive advantages and the resources they possess. Therefore, the advantage is not fully understood by competitors, and for that reason, it is difficult for them to duplicate it.

There is consensus among the three main categories that encompasses intellectual capital: human capital, organisational (or internal) capital and external capital [43].

Human capital is defined as the individual knowledge stock of firms that is represented by workers and their capacity to generate and learn it. According to [44], it can be measured based on training, skills and knowledge.

External capital, also known as relational capital, refers to the network with external stakeholders, such as customers and suppliers, social responsibility activities and customer satisfaction and loyalty [45]. External capital is defined as the values, behavioural rules, codes and common objectives between customers and suppliers that result from collaboration and integration, thanks to an alignment of vision and organisational culture [46].

Establishing a distinctive and nonimitable combination of the resources and capabilities that make up these capitals is a generator of competitive advantages for organisations. The relevance of external capital with the supply chain, highlighting the relationship that organisations have between customers and suppliers, is the main reason for selecting this kind of capital in the current study. This analysis focuses on the role that external capital plays in the adaptive capacity of supply chains, considering the principles of circularity.

4. Building the Circular Network in the Resilient Supply Chain

The transition to a sustainability-based approach requires a shared vision among all stakeholders along with a collaborative approach. Manufacturing companies must care more about how to minimise environmental damage, implementing circularity into supply chains and stimulating their innovation, efficiency and cooperation between actors implied by such suppliers and customers [47]. Most studies on supply chain coordination do not take into consideration product quality from an environmental point of view and consumers' environmental concerns [48].

Vertical and horizontal cooperation in closed-loop supply chains decreases emissions and costs [49]. Based on the principles of circularity, collaboration networks are established with suppliers and customers on a broad basis, both in terms of number and in terms of the activities involved. This enables the incorporation of new raw materials and new processes and the recovery of end-of-life products into the manufacturing and distribution processes. To this end, connection and trust must be fostered through more active and transparent knowledge and information flows [20].

This requires establishing routines that allow actors to be aware of and take responsibility for the different practices related to technical, social or administrative aspects. External capital is a crucial factor for organisations, and it helps for building remarkable capabilities for the whole supply chain [47].

In terms of external capital, organisations can create competitive advantages by accessing, using and acquiring resources and developing capacities in their supply chains [47]. Regarding supplier-related routines, the focus should be on working towards the establishment of long-term relationships with a large number of suppliers.

4.1. The Establishment of Knowledge Flows through Supply Chain Intelligence Integraton (SCII)

Supply chain relationships and interactions strive to improve the environmental collaboration between buyers and suppliers [50]. The implementation of the circular economy requires the approval of all actors in the supply chain [18]. The aim of circularity is to achieve waste reduction and return resources to the production cycle. Coordination and cooperation with suppliers are crucial to supply restorative, recoverable and regenerative raw materials, with less negative effects on the environment [34].

Establishing a closer relationship with customers and suppliers implies a differentiator advantage. External capital in supply chains promotes common actions, and it allows forming stronger relationships. Routines that collect and process information and integrate innovation play a key role to achieve effectiveness and efficiency in external coordination with suppliers and customers. Engineering design choices must be linked, on the one hand, to coordination with suppliers and their components and factories and, on the other hand, to the experience of customers [51]. These dynamic capabilities are necessary to achieve better coordination and cooperation with suppliers and customers, and that is why all agents involved in the supply chain must work in line with each other to succeed in implementing circular models.

External capital implies the accessibility to external knowledge embedded in interorganizational relationships and in networks within suppliers and customers [46]. Good relationships with these external agents improves communication along the supply chain and facilitates the integration of diverse knowledge [52]. In order to leverage the benefits of knowledge incorporated in the supply chain network, organisations must invest in their external capital [46]. Furthermore, external capital and collaboration in supply chains increase the innovation [53] and process redesign, a key element for implementing circular practices, promoting interdependence of resources, information and communication between the companies and parties engaged. In a transaction, trust is the ability to believe and trust the other party, which is crucial for purchase intention [54]. So-called "green trust" involves consumers' confidence that it will be an environmentally sustainable product. To achieve this, it is essential to establish two-way knowledge flows between the organisation and the stakeholders involved in the supply and distribution process [20].

Organisations enhance their collaboration and relationships with supply chain partners, suppliers and customers when they possess valuable knowledge resources. The long-term partnership that takes place with supply chain agents is based on the exchange of knowledge, resources and information through fluid communication between the parties. Shared values and culture, satisfaction, commitment, trust, coordination and collaboration are key points [55].

External capital plays a key role in achieving transparency in the relationship between actors implied in the supply chain [56]. Transparency provides information about the interaction and relationship of both parties that can create value and enhance competitive advantage, commitment and satisfaction between the agents. Cooperation along the supply chain enhances partnerships [57]. The relationship between supply chain actors is called partnership and follows transparency, as it involves a close long-term relationship with open communication, mutual coordination of efforts and joint planification [58].

Suppliers and customers' knowledge are crucial as external sources in addition to applying internal knowledge to conduct innovation practices in organisations [59]. The knowledge obtained from suppliers and customers could improve a firm's customer satisfaction and operational and green performance [60]. The knowledge embedded in supply chain networks is called supply chain intelligence (SCI), whilst the application and absorption of knowledge from supply chain collaborators is a process denoted as supply chain intelligence integration (SCII) [61]. SCII integrates knowledge application from organisations and knowledge absorption by supply chain partners [40]. External capital supports SCII knowledge processing [62], which is crucial for an organisation's innovation practices. Supplier intelligence integration promotes a more efficient application and a rapid absorption of knowledge from suppliers, which helps to adjust productivity when environments change quickly [63]. Likewise, customer intelligence integration analyses a greater understanding of customer demands, needs and expectation from the market [59].

Consequently, we postulate that:

Proposition 1 (P1). *Supply chain intelligence integration (SCII) positively affects circular networks in resilient supply chains by supporting and sharing knowledge between suppliers and customers.*

4.2. The Establishment of Greener Logistics and Intelligent Transport through Industry 4.0

In terms of pollution, suppliers have a high environmental impact, which is why cooperation and coordination with them is necessary to achieve a greener product [64]. Organisations have the option to select suppliers with environmental and social standards and who have implemented so-called "reverse logistics" based on remanufacturing and waste management. This is key to the development of reverse logistics, the consideration of waste and how it is managed [23]. In reverse logistics, resources that have become obsolete are moved between companies in order to provide for their favourable disposal or to recapture their value [65]. The right choice of suppliers can boost material circularity and reduce environmental damage [64].

Industry 4.0 plays an essential role in sustainability in organisations, highlighting the improvement of logistics and intelligent transport management. It could have an impact on promoting greater monitoring of sustainable principles, "green" consumer behaviour, increasing product visibility throughout its life cycle and decreasing operational and development costs [66]. Industry 4.0 encompasses artificial intelligence, 5G networking, the Internet of things (IoT), robotics, blockchain, augmented reality and 3D printing, among others [67]. Currently, there are numerous programmes to make logistics management greener through distributed manufacturing systems and self-driving vehicles [68]. Furthermore, external capital can be related to the right information and communications technology (ICT) management, and R&D investments are influenced by industry 4.0 [69]. As [66] point out in their study, Industry 4.0 makes the exchange of knowledge and information along the supply chain more transparent and improves decision making between different parties. Digital technologies offer opportunities to integrate and implement the circular economy in supply chains [66]. Consequently, we postulate that:

Proposition 2 (P2). *Industry 4.0 positively affects circular networks in resilient supply chains by achieving greener logistics and intelligent transport.*

4.3. The Optimisation of the Supplier Selection Process through Ethical Codes and Multicriteria Tools

The composition of certain products supposes that when discarded at the end of their lifespan, they are major pollutants that harm human health, which is why environmental collaboration in the supply chain is important. The most crucial elements for a more circular supply chain are low carbon emissions, sustainability, and green suppliers [70]. The selection of suppliers affects the behaviour of environmentally responsible organisations [71].

Suppliers should be selected on the basis of their sustainable or green performance, taking into account aspects such as sustainable product packaging, use of renewable energy, recycled items and reduction of emissions associated with manufacturing and transportation [72]. To optimise the supply chain network, it is important to detail the most efficient location of facilities and the necessary connections in order to reduce carbon emissions and associated costs [73]. Reducing transport and promoting local supplier relationships is one of the recommendations to implement more circular practices [74]. Recent practical examples support this trend. Permanent magnets, a component used in various technological products such as mobile phones and cars, are made from rare earth that is mined in developing countries without any environmental safeguards. In the circular current, the use of recycled raw materials and a manufacturing change of raw materials are being encouraged, and consequently, a search for more environmentally friendly suppliers available in nearby markets is also being encouraged. These sustainable practices by suppliers are recognised through environmental certifications, such as ISO 14000, which allow the most ecoefficient suppliers to be identified [74]. The circular economy encompasses new ethical relationships and moral requirements throughout the supply chain, according to the sustainable and circular value principles. New production methods were initiated based on ethical codes and attitudes which respect the environment. This requires a circular economy development model to establish new production ethical codes guidelines, such as emission reductions, cleaner production and resource conservation, integrating long-term interests within suppliers [75,76].

It is therefore recommended that ethical codes be established for the selection of suppliers, setting out the principles and features they must comply with in order to be part of the network.

Supply chain partnerships have improved due to globalisation and computerisation [70]. A better supplier selection can be achieved using IT tools such as big data or data mining to study the environmental impact of suppliers. Several green supplier ranking tools exist, such as the linguistic entropy weighting method, LEWM, which evaluates the different possibilities. The authors of [77] conducted a study in which they take into account environmental issues to put pressure on actors involved in supply chains. Multicriteria decision-making approaches, MCDM, are used to select suppliers through evaluation [74], and another method of note is the analytic hierarchy process, AHP [78]. Ecodesign capabilities, compliance with legislation, codification, pollution control, green competencies, product recycling, environmental efficiency, use of clean energy and materials and green image, among others, are the main selection criteria [74].

Thus, the following is being proposed:

Proposition 3 (P3). *Ethical codes and multicriteria tools positively affect circular networks in resilient supply chains by improving the supplier selection process.*

4.4. The Establishment of a Strong Relationship Based on Supplier's Trust and Commitment

One of the most important criteria when engaging with a supplier is to establish an appropriate level of commitment [77]. Sustainable and circular supply chain practices and collaboration within the supply chain are facilitated by suppliers' trust in the organisations they engage with [79]. Trust is a good mechanism for organisational control and for improving supply chain performance and fostering interfirm relationships [80].

Supplier trust, information and knowledge sharing and collaboration and communication are key aspects of supplier relationships. Providing support, motivation, training, assistance and active participation by allowing suggestions or feedback gives suppliers confidence in organisations. In addition, reward mechanisms have a positive effect on engagement [79].

Proposition 4 (P4). *Assistance, active participation and reward mechanisms positively affect circular networks in resilient supply chains by improving the suppliers' commitment.*

4.5. The Establishment of Customer Acceptance through Warranty Policies, Additional Services and New Service-Oriented Contracts

Collaborating with consumers in process and product innovation is essential for companies for applying new knowledge and customers' preferences that are changing rapidly [81]. Companies can be more adaptative to the changes because of the supplier and customer partnership and the transferring of knowledge [82]. This implies a key factor towards circularity, e.g., in terms of customer's green behaviour, for recycling or remanufacturing. Repair extends the lifespan of many products, which can be designed to have a long service life or can be extended through repair, refurbishment and remanufacturing. Furthermore, through recycling it is possible to close the loop [83].

Market acceptance of remanufacturing is low as consumers think of lower quality products; when customers understand that remanufactured products use less energy, are less resource intensive and have ecological benefits, customer acceptability will increase [84]. Experience and satisfaction with previous purchases also play an important role [85]. The marketing of remanufactured products implies a challenge for organisations, highlighting the low incentives to buy remanufactured products [86].

Refurbishment is an environmentally beneficial strategy that contributes to the circular economy by bringing back used products and repairing or replacing components [87]. The concept of refurbishment is often unclear to consumers, and the lack of attractiveness of these products and their unavailability in all markets are the main barriers [88].

It is important to provide information to raise consumer awareness; the use or purchase of remanufactured products can be encouraged through new ways of consuming a product based on use rather than purchase, complementarity through additional services or by extending the warranty against malfunctions [88,89]. Product price is affected by warranty duration and reliability and plays a determining role in the efficiency and profit of the supply chain. The performance of the closed-loop supply chain is affected by the warranty period, which in turn fixes the reliability of products and perceived value [90]. A strong relationship with customers is imperative to engage in reuse, recycling and take-back activities and to incorporate new business models such as collaborative consumption [91]. The leasing contract allows the customer to use an asset in exchange for the payment of lease rentals with the option to buy the leased asset, return it or renew the contract.

Hence, we formulate:

Proposition 5 (P5). *Warranty policies, additional services and new service-oriented contracts positively affect circular networks in resilient supply chains by increasing customer acceptability of remanufactured or refurbished products.*

4.6. The Establishment of Customer Participation and Purchase Promotion through Enviromental Education, Rewards and Discounts

Product-service systems (PSS) enable resource recovery, reuse, and recycling. Several studies report how circularity influences consumer behaviour by changing their role to a more active one in closed-loop systems [92]. Effectively collected resources can be used again in their life cycle; at this point, consumers play a crucial role, because the quality of revalued goods is improved by the key activities of separation, sorting, storage, collection and disposal [93]. In the linear economy, consumers were the last link in the supply chain, playing a passive role, but in the circular economy they are actively involved in the recovery and recycling of products and waste [94].

Customers can follow more sustainable purchasing behaviours by purchasing products that are less harmful to the environment, thus lowering environmental and social impacts [95]. Raising awareness of circular consumption through policies is imperative [23]. Consumers are key stakeholders in the return of products when they become obsolete and determine the success of circular systems [96].

Encouraging consumer proactivity and efforts to reflect green thinking in their consumption patterns is critical to the successful implementation of circular relationships [97]. Through environmental education campaigns or programmes, customers can understand the importance of sustainable purchasing behaviour [98]. It is important to make consumers aware of the quality and environmental impact of the products they buy by providing them with additional information. Translating environmental data into understandable information influences sustainable consumption [99].

Consumer awareness is defined as the level of consumer awareness of their responsibility towards the environment and of information about the alternatives they have in the market. However, there are barriers that can interfere with the positive effect that awareness has on changes in consumer behaviour. For example, there may be a lack of alternatives or price increases for ecoresponsible products [100].

Individual consumer behaviour can be measured and predicted based on their purchase intention, according to the theory of reasoned action (TRA), although factors can change attitudes and interfere [101]. The company should look for factors that encourage consumers to buy or participate in certain circular processes. These tools would facilitate processes such as the establishment of rewards or discounts.

To improve purchasing behaviour, organisations could apply financial rewards or discounts on future purchases to motivate consumers to participate, for example, in sending their products to collection or recycling points, among other measures [98]. On-site collection services and exchange of used products for a reduction in the purchase price of new products are other incentive measures that circular organisations can use in the development of their external capital [102]. It is necessary for companies to explore the incentives they can use with their consumers to change their purchase intention and their motivations to participate in product returns [103].

The willingness to pay a higher price for a product that has been produced in a more environmentally friendly way is a critical point to address. However, by raising consumer awareness, consumers can be made willing to pay more for a product produced in a more ecoefficient way, which reduces the environmental and social impact [95]. In order to make consumers willing to pay a higher price for a product resulting from the implementation of a circular system, an awareness or educational process is required. However, in the early stages of developing environmental awareness, it is key that green products are priced competitively in order to be attractive [104]. Some studies [105] argue that the higher the discounts are for returning used products, the more effect on customers' decisions.

According to the literature, we can postulate that:

Proposition 6 (P6). *Environmental education, rewards and discounts positively affect circular networks in resilient supply chains by increasing customer purchase promotion and participation in product recovery processes.*

5. Designing a Conceptual Model

This section illustrates the design of the conceptual model where the links between the elements studied are identified. The model proposed seeks to fill the gap in the literature by taking into account the importance between the key role of customer–supplier relationships in order to implement more circular and resilient supply chains.

Six main propositions have been suggested. The first (P1) outlined that supply chain intelligence integration (SCII) positively affects circular networks in resilient supply chains by supporting and sharing knowledge between suppliers and customers. The second proposition (P2) argues that Industry 4.0 positively affects circular networks in resilient supply chains by achieving greener logistics and intelligent transport. The third proposition (P3) notes that ethical codes and multicriteria tools positively affect circular networks in resilient supply chains by improving the supplier selection process. The fourth proposition (P4) indicates that assistance, active participation and reward mechanisms positively affect circular networks in resilient supply chains by improving the suppliers' commitment.

The fifth proposition (P5) highlights that warranty policies, additional services and new service-oriented contracts positively affect circular networks in resilient supply chains by increasing customer acceptability with remanufactured or refurbished products. Finally, the sixth proposition (P6) states that environmental education, rewards and discounts positively affect circular networks in resilient supply chains by increasing customer purchase promotion and participation in product recovery processes.

The conceptual model (Figure 2) offers an overview on the connections among the topics studied and their linkage between the customer–supplier relationship and circular supply chains. The model demonstrates the connection between external capital and circularity in order to achieve more resilience in supply chains. Transparency plays a key role in providing information about the interactions. Relationships with suppliers and customers imply the access to the external knowledge embedded, SCII [61]. SCII supposes a rapid absorption of knowledge from suppliers and a better understanding of customers' needs, highlighting the importance of an appropriate level of commitment with suppliers and taking into account that motivation, support, assistance and training improve confidence in organisations.

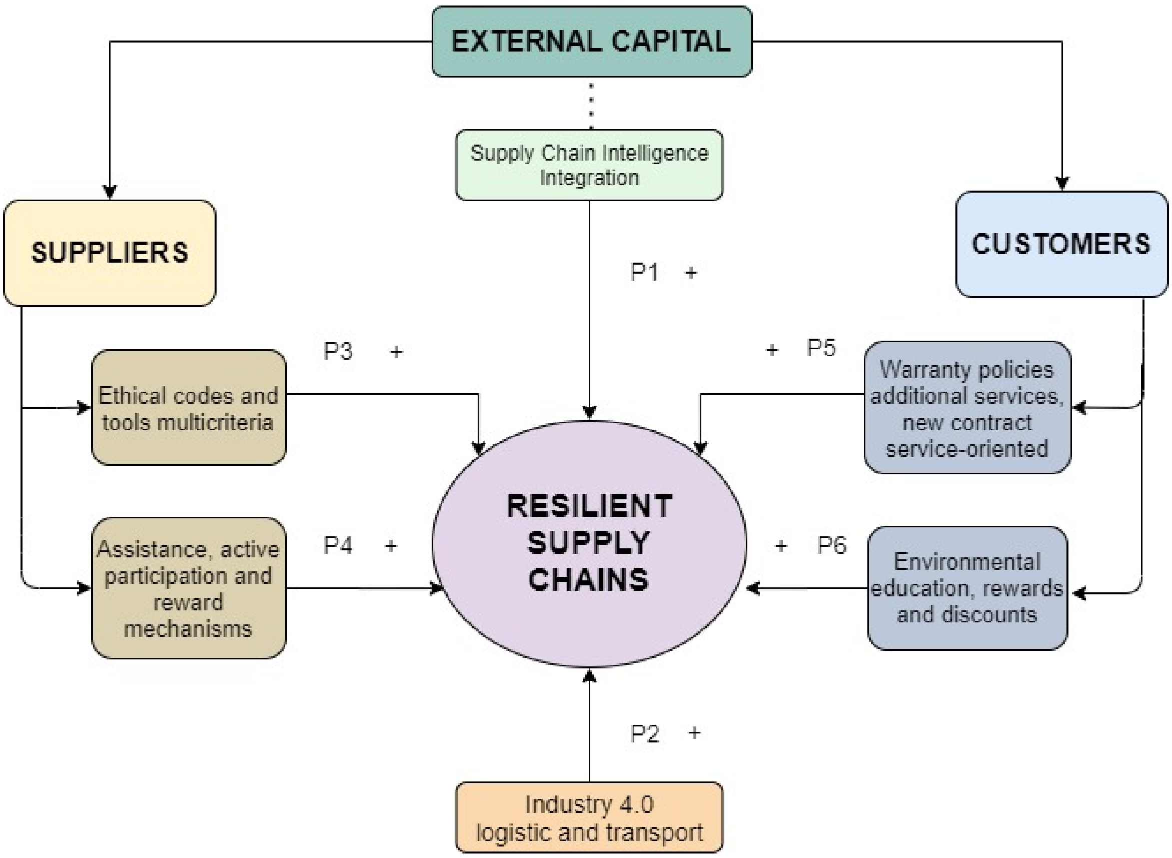

Figure 2. Conceptual model.

Organisations must select those suppliers with environmental concerns and those that develop reverse logistics. The implementation of logistics and intelligent transport management is possible thanks to Industry 4.0, which makes the exchange of knowledge and information throughout the supply chain more transparent between parties. For instance, multicriteria tools such as MCDM or AHP resulted in a greater supplier's selection [74,78].

On the other hand, providing information to raise consumer awareness is key. Warranty periods and leasing options increase customer acceptability with refurbished and remanufactured products [89,106]. Applying financial rewards or discounts on future purchases motivates customers to return used products according to circularity practices. Furthermore, educational environment campaigns encourage customers to participate actively in product recovery [107].

6. Conclusions

The COVID-19 pandemic has affected the functioning of supply chains in a way never seen before [11]. This has meant the disruption of organisational operations due to a lack of supply and mobility problems that have prevented the development of transport for a prolonged period. Organisations need to be resilient and adapt the functioning of their networks [3,36]. Many sectors are moving towards sustainable practices achieving resilience, such as automotive production and the technology components industry. Sustainability is an element that could build resilience, and both concepts pursue sustainable development [108].

The implementation of sustainable strategies can facilitate such changes, as it can have economic, social and environmental benefits. Therefore, applying the principles of circularity is a step forward on the road to sustainability for organisations. The circular economy is a revolution at a relational, production and technological level. This implies the establishment of new knowledge flows, which requires the establishment of routines and tools to facilitate them [20].

Based on the intellectual capital-based view theory (ICV), this study aims to provide an operational framework for the circular relationships that are established in circular supply chains. In particular, the external capital that facilitates and optimises knowledge flows with actors outside the organisation has been analysed [24]. Applying the principles of circularity to the supply chain allows new rules to be established with suppliers and customers. It increases the number of actors with an active role in greener operations. A long-term partnership between customers and suppliers is fundamental to achieve social and environmental solutions [109]. The design of new networks in supply chains needs to be further analysed to achieve resilience, effectiveness and efficiency through circularity [18].

The contributions in this article can be differentiated between theoretical and practical contributions.

6.1. Theoretical Contribution

Several current studies, mainly empirical, focus on the productive and technological aspects of the circular economy. Throughout this paper, we aim to contribute to the construction of a theoretical basis that focuses on the management of circular network relationships. Intellectual capital-based view theory (ICV) provides us a framework for action that favours knowledge flows in supply chain relationships [24]. We therefore focus on external capital. Although there is literature linking external capital to sustainability, there is a significant gap in the relationship between external capital and circularity.

Even though this conceptual model is exploratory, what is developed in this research provides theoretical contributions to the circular supply chain the literature, thanks to the linkage presented between customer–supplier relationships and circularity, filling this gap in the literature.

6.2. Practical Contribution

External capital proposes the establishment of routines and tools that facilitate the flow of knowledge from actors outside the organisation. In this sense, our study postulates the use of this framework in order to favour relations with suppliers and customers under the principles of circularity [47,51]. Organisations must take advantage of the necessary investments and organisational changes that must be made to adapt to the new postpandemic scenario to make a real commitment to sustainability [47].

It is essential to establish a climate of trust with both suppliers and customers. The development of training and information programs in the target markets modifies the behaviour and consumption patterns of customers by considering the principles of sustainability [79]. However, the effects of these programs are not immediate, so complementary tools must be put in place to build customer confidence.

To this end, the use of specific guarantees and the offer of complementary services are proposed. In addition, companies must adapt to new consumption patterns that focus on use rather than possession. Therefore, the offer of companies must be adapted to this. Accompanying a new offer, the use of discounts would also allow the customer to buy or carry out circular activities [105].

To build trust with suppliers, activities are proposed to enable the organisation to maintain a closer relationship with them. Through a reward system, if certain standards are met and advisory and support services are established, suppliers will be more likely to adopt circularity principles in their value chain [79,107]. In addition, the establishment of ethical codes and supplier selection systems through multicriteria tools will help to ensure that suppliers are more likely to adopt circularity principles in their value chain [75,76].

6.3. Limitation and Future Recommendation

In the literature review, we have found a majority of papers that consider intangible capital with sustainability. This shows that it is still a developing field of research. Our research has focused on the application of external capital, given the importance of relationships in supply chain development, with much of the research focused on the operational and technological part of the process [110]. However, in future research, it would be interesting to study the joint effect of the three types of intellectual capital. Similarly, their practical application in different sectors would allow us to establish useful empirical evidence to adapt or extend the proposal offered.

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ARTICLE III

TOWARDS CIRCULAR ECONOMY PRACTICES IN FOOD WASTE MANAGEMENT: A RETROSPECTIVE OVERVIEW AND A RESEARCH AGENDA

ARTICLE III. TOWARDS CIRCULAR ECONOMY PRACTICES IN FOOD WASTE MANAGEMENT: A RETROSPECTIVE OVERVIEW AND A RESEARCH AGENDA

The third and final article of this thesis address a bibliometric analysis to provide a research overview about circularity application in food waste management, its state-of-the-art and future opportunities in the field. Firstly, it presents the evolution of the number of publications, the most influential journals in the field, along with the most representative authors, institutions, countries and research areas. Secondly, using the co-occurrence analysis of keywords by VOSviewer and SciMat, it is examined the thematic organisation of the field to discover research hotspots. Food waste valorisation, the recovery processes and the use of cleaner and renewable energy are the main research topics. Thirdly, an agenda is proposed to guide for future research in the domain, highlighting the required consideration of social issues, regulatory support is needed SDGs implementation in waste management, waste measurement differentiating, and the development of new technologies involved.

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Abstracts, Global Health, Health & Safety Science Abstracts, Health Source, Horticultural Science Abstracts, Hospitality and Tourism Index, Innovative, INSPEC, International Food Safety News (ISI), Maize Abstracts, Manning & Napier, MasterFILE, Medicine & Health, Nutrition Abstracts & Reviews, OCLC, Ornamental Horticulture, Pig News & Information, Plant Breeding Abstracts, Plant Genetic Resources Abstracts, Postharvest News & Information, Potato Abstracts, Poultry Abstracts, Proquest central, ReadCube Discover, Research Alert, Review of Agricultural Entomology, Review of Aromatic & Medicinal Plants, Review of Medical & Veterinary Entomology, Review of Medical & Veterinary Mycology, Review of Plant Pathology, Rice Abstracts, Rural Sociology Abstracts, Science Citation Index (ISI), SciSearch (ISI), Seed Abstracts, Soils & Fertilizers Abstracts, Soybean Abstracts Online, Sugar Industry Abstracts, SUNCAT, Telebase, Tropical Diseases Bulletin, Wheat, Barley & Triticale Abstracts, World Agricultural Economics, World Agriculture.

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Dear Prof. ALONSO-MUÑOZ,

This letter is to confirm that your manuscript *"TOWARDS CIRCULAR ECONOMY PRACTICES IN FOOD WASTE MANAGEMENT: A RETROSPECTIVE OVERVIEW AND A RESEARCH AGENDA"* has been accepted for publication for **British Food Journal** on 12th July 2022.

I would like to thank you for your contribution to the journal, on behalf of Emerald Publishing and the editorial team of **British Food Journal.**

Best regards,

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TOWARDS CIRCULAR ECONOMY PRACTICES IN FOOD WASTE MANAGEMENT: A RETROSPECTIVE OVERVIEW AND A RESEARCH AGENDA

Abstract

Purpose – This study offers a research overview of circular food waste management, covering key themes and trends. It analyses state-of-the-art research in this field and proposes an agenda to guide future research.

Methodology – This study outlines bibliometric analysis from a sample of 349 articles with VOSviewer and SciMat software to identify research trend topics.

Findings – Our findings reveal a substantial amount of interest in this field. The main research topics relate to the recovery processes and valorisation of food waste and its conversion into renewable and cleaner materials or energy sources, towards circularity. However, these processes require consideration of social aspects that facilitate their implementation, which are currently under-researched.

Practical implications – Companies can target their circular food waste management by considering three key aspects. Firstly, the establishment of closer and more sustainable relationships with various stakeholders. Secondly, a regulatory framework and the support of institutions are both required for the correct implementation of circularity. Finally, what is not measured does not exist. It is therefore necessary to establish indicators to measure both the level of development of circularity in waste management and the fulfilment of the established objective.

Originality/value – This bibliometric analysis looks at the application of circularity principles in food waste management from a holistic perspective, considering different areas of knowledge.

Keywords food waste, waste management, circular economy, supply chain, bibliometric analysis, research agenda, thematic analysis, research hotspots

Paper type Research paper

1. Introduction and background

Achieving a more sustainable food system is relevant in terms of both economic efficiency and new ethical standards in our society. This interest has been intensified by the need to achieve the Sustainable Development Goals (SDGs) that would enable improved food security and sustainability (Santeramo, 2021). Specifically, SDG 12.3 for the fulfilment of the 2030 Agenda, which highlights the importance of halving, per capita, food waste at retail and consumer levels and reducing food losses along production and supply chains (United Nations, 2015; Närvänen, Mesiranta, Mattila and Heikkinen, 2020). This requires a break with the current linear system of the food supply chain, based on value chains inspired by the expression "from field to fork" (Béné, Oosterveer, Lamotte, Brouwer, Haan, Prager, Talsma and Khoury, 2019). In these linear food systems, raw materials are extracted and transformed into final products. Final consumption or generation of food waste is disposed of with little reuse or recovery. A change that is already reflected in Ericksen's seminal work (2008, p. 2) and referred to as "feedback loops". New trends for a more sustainable food industry require further research. One such trend argues for an application of circularity principles to the food supply chain (Santeramo, 2021).

Food waste is a part of biodegradable waste, discharged by humans, which reflects environmental and health issues (Paritosh, Kushwaha, Yadav, Pareek, Chawade and Vivekanand, 2017). UNEP (2021) The Food Waste Index Report calculated that in 2019, around 931 million tons of food waste were generated: 61% from households, 26% from food services and 13% from retail. Food waste is particularly common in developed countries (Börühan and Ozbiltekin-Pala, 2022). In Europe, around 50% of the global municipal solid waste is food waste (Ananno, Masud, Chowdhury, Dabnichki, Ahmed and Arefin, 2021). Thus, new methods of food waste management are required in its treatment (Pattnaik and Reddy, 2010; Paritosh *et al.*, 2017).

The benefit of reducing food waste from a circular perspective has environmental, economic, and social impacts. At the environmental level, food waste is considered a great contributor to climate change and greenhouse gas emissions and a large consumer of energy or materials (Krishnan, Agarwal, Bajada and Arshinder, 2020; Närvänen *et al.*, 2020). From an economic perspective, circular waste management reduces costs and results in lower food prices (Despoudi Bucatariu, Otles and Kartal, 2021). At the social level, reducing food waste through the utilisation of unwanted food is beneficial for alleviating hunger (Chauhan, Debnath and Singh, 2018).

Circular supply chain management involves all functions of a supply chain by exercising greater control over all stages or processes with increased efficiency, resulting in greater reductions to cost and higher levels of food quality and safety (Corrado and Sala, 2018; Krishnan *et al.*, 2020, Närvänen *et al.*, 2020). Closed-loop food supply chain implies a circular economy approach with the use of reverse logistics systems, by means of food waste recycling and reuse (Jabbour, Frascareli, González and Jabbour, 2021).

In the food supply chain, waste and loss occur at different points in the food value chain (Schuster and Torero, 2016). Food loss occurs in the early stages, such as in production, while food waste takes place in the subsequent stages; mainly focused on food distribution and consumption (Parfitt, Barthel and Macnaughton, 2010). Since application of the circular principles involves differing approaches, depending on the phase analysed, this study has focused on waste management as it affects more stages of the supply chain.

Indeed, recent studies highlight the need for further research on the implementation of circularity, considering aspects such as improved processes: collection, storage, the adoption of new technologies and the creation of new infrastructure and transport (Ciccullo, Cagliano, Bartezzaghi and Perego, 2021; Santeramo, 2021). Similarly, further knowledge related to new behaviours and the establishment of cooperative arrangements with other actors is needed. New routines and habits among consumers and retailers are required for the reduction of food waste from a circular and green economy perspective (Aschemann-Witzel, de Hooge, Rohm, Normann, Bossle, Grønhøj and Oostindjer, 2017; Welch, Swafeld and Evans, 2018; Santeramo, 2021).

Bibliometric studies on food waste management have been published, focusing on aspects such as: 1) the context in which it is produced - the urban context (Zhong, Wang and Cui, 2021) or in the coffee sector (Kourmentza, Economou, Tsafrakidou and

Kornaros, 2018), 2) the processes or technologies with which it is produced or related, - the food loss-food waste and food safety nexus (Santeramo and Lamonaca, 2021), the food waste hierarchy (Teigiserova, Hamelin and Thomsen, 2020) or digitisation in food supply chains (Rejeb, Rejeb, Abdollahi, Zailani, Iranmanesh and Ghobakhloo, 2022).

There are previous bibliometric articles associating waste management with the circular economy, yet in specific aspects, focusing mainly on processes such as recovery, waste-to-energy, biorefinery, anaerobic digestion and pyrolysis (Germar, Soler and Sánchez-Teba, 2021). Context has also been considered in the analysis of the reviewed works. For instance, municipal solid waste management (Tsai, Bui, Tseng, Lim and Hu, 2020) or the crisis state marked by Covid-19 and healthcare waste management (Ranjbari, Esfandabadi, Schevchenko, Chassagnon-Haned, Peng, Tabatabaei and Aghbashlo, 2022a; Ranjbari, Esfandabadi, Gautam and Ferraris, 2022b). Two of these papers focus on specific aspects of the food sector. Casallas-Ojeda, Torres-Guevara, Caicedo-Concha and Gómez (2021) examined the cheese whey transformation into energy by means of anaerobic digestion. Ranjbari, Saidani, Esfandabadi, Peng, Lam, Aghbashlo, Quatraro and Tabatabaei (2021) analysed research topics related to circular food waste management highlighting the bioplastic-based food packaging.

Our bibliometric analysis makes a new contribution to those already published by considering food waste management and the circular economy from a holistic perspective. Regarding the fragmentation of research on this topic and its markedly technical nature, it is necessary to reflect on state-of-the-art research and guide future research from a comprehensive and managerial standpoint. Research is at its most useful when it reaches practical application. Therefore, its development should facilitate the implementation of the concept under study. To provide a research overview on the application of circularity in food waste management and the main trends of research, this paper proposes the following research questions:

RQ1. What is the historical evolution of the literature on circular economy and food waste?

RQ2. Which are the most influential journals, authors, countries and institutions that have published content on this research topic?

RQ3. What is the conceptual structure in this research stream?

RQ4. What are the future research agendas and patterns related to circular economy and food waste?

This paper is structured as follows. Following the introduction and literature background, the methodology and bibliometric results are presented as: 1) the historical evolution of publications, 2) the most influential journals in the field of circular economy and food waste; authors, countries and institutions most cited and the research areas involved, 3) thematic organisation in the field, using the co-occurrence analysis by VOSviewer and SciMat to detect research trends. Subsequently, we established key points for the development of a research agenda: the discussion, and finally, the conclusions.

2. Methodology

This paper employs bibliometric analysis methodology combined with thematic analysis of the literature, considering articles that contain the most co-occurrent keywords. In this way, research hotspots are identified, to support the proposal of a research agenda. This analysis allows us to make theoretical and practical contributions of interest to researchers and practitioners.

To synthesise previous studies and findings, it is essential to study the relationship between knowledge elements, such as keywords in co-word analysis (Cobo, López-Herrera, Herrera-Viedma and Herrera, 2011). Bibliometric methods follow a quantitative approach of visual representation that is widely used in fields such as management, entrepreneurship or innovation. These methods provide evidence to explore the connections of the intellectual structure of a field of study (Zupic and Cater, 2014; Donthu, Kumar, Pandey and Lim, 2021). By interpreting bibliographic data, it is possible to identify the evolution and currents of research (van Eck and Waltman, 2010) and eventually characterise the state of development of a specific field (Boyack and Klavans, 2014; Powell, Kouropalatis, Morgan and Karhu, 2016; Garousi and Mantyla, 2016). The citation analysis, and co-occurrence analysis are the main methods that we used in the present paper.

Figure 1. Methodological process

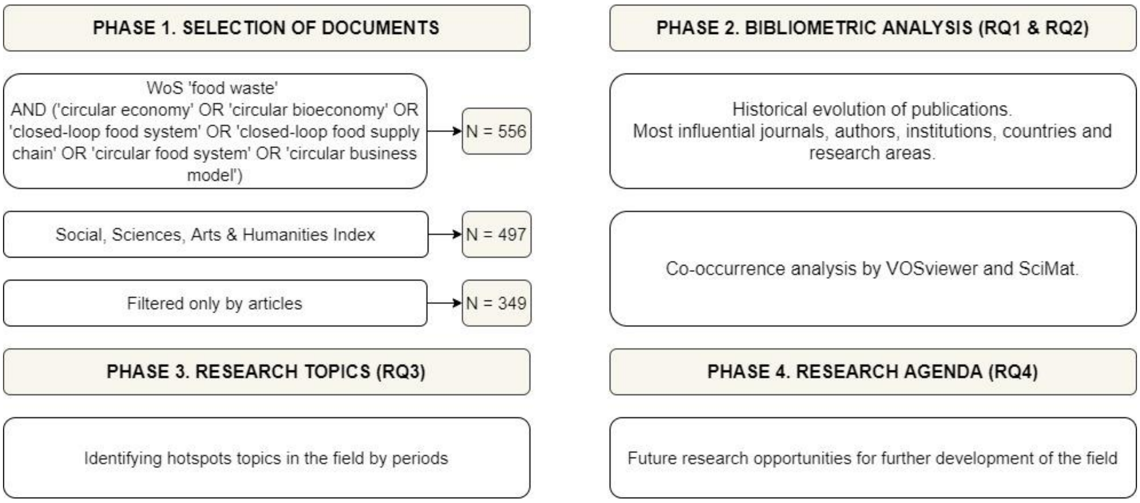


Figure 1 shows the methodological process carried out in this article which is divided into four phases: 1) data collection, 2) bibliometric analysis, 3) research trend topics identification and 4) research agenda.

For the data collection, documents were retrieved from the Web of Science Database, December 2021. The selection of documents was carried out combining the terms: "food waste" AND ("circular economy" OR "circular bioeconomy" OR "closed-loop food system" OR "closed-loop food supply chain" OR "circular food system" OR "circular business model"). The terms were filtered by topic, including title, abstract and author keywords, within the period 2015 to 2021, obtaining 556 results. Then, we sorted this by Social, Science Citation Index and Arts & Humanities Citation Index, retrieving 497 papers. Finally, we excluded Conference Proceedings Citation Index and Book Citation Index, filtered only by articles, and obtaining a total sample of 349 documents.

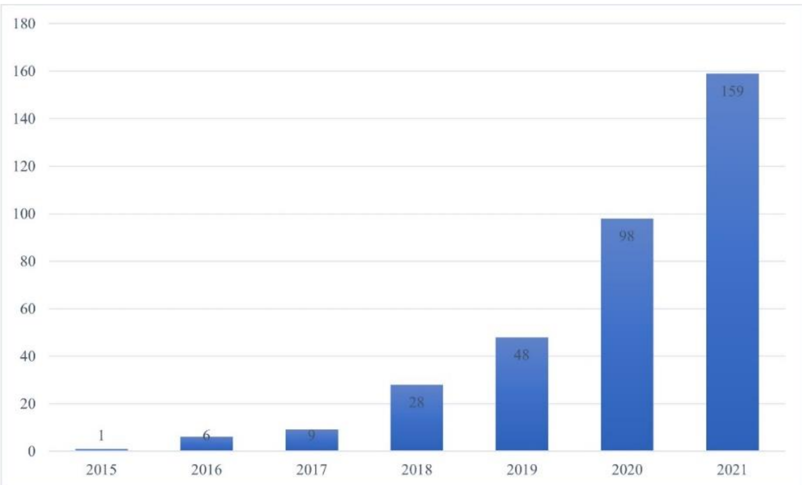
In the second phase, we examined the historical evolution of publications, the most influential journals, authors, institutions, countries and research areas on the subject. Then, we conducted a co-occurrence analysis by VOSviewer and SciMat software to analyse the thematic organisation. Both are utilised to perform a co-word analysis (keyword co-occurrence). 1) VOSviewer tool is used to map the scientific research topics in the entire period under review (2015-2021) and to identify the research trend topics according to: the occurrences, the average publication year, the average citations and the link strength between keywords (phase 3). 2) SciMat provides a strategic diagram for period 2 (2020-2021), which serves to analyse, in detail, the research trend topics (phase 3). Finally, in the fourth phase, we proposed a research agenda for future opportunities and further development of the field.

3. Results

3.1. Historical evolution of publications

Figure 2 shows the evolution of publications in the field. Since 2015, there has been an increase in papers published, coinciding with two important milestones: The 2030 Agenda for Sustainable Development approved by The United Nations General Assembly; and the Circular Economy Package by The European Commission. Hence, this field is gaining momentum for research (Rizos, Behrens, Kafyeke, Hirschnitz-Garbers and Ioannou, 2015). The years 2020 and 2021 are the most representative, and for that reason, a section about trending topics in the field is covered in this work.

Figure 2. Historical evolution of publications in the field



3.2. Most influential journals

Table 1 shows the most productive journals in the field. These sources represent 47.85% of the total sample, which means 167 articles from 349 documents, retrieved by WoS.

Table 1. The most representative journals in the field

Journals	JCR (2021)	Quartiles	Category	C	D	%
Journal of Cleaner Production	11.072	Q1 (24/279)	Environmental Sciences	1,032	41	11.75%
Waste Management	8.816	Q1 (36/279)	Environmental Sciences	607	23	6,59%
Science of the Total Environment	10.753	Q1 (26/279)	Environmental Sciences	589	18	5,16%
Sustainability	3.889	Q2 (133/279)	Environmental Sciences	378	29	8,31%
Bioresource Technology	11.889	Q1 (13/119)	Energy & Fuels	313	10	2,86%
Resources Conservation and Recycling	13.716	Q1 (12/279)	Environmental Sciences	246	13	3,72%
Renewable & Sustainable Energy Reviews	16.799	Q1 (8/119)	Energy & Fuels	238	11	3,15%
Energies	3.252	Q3 (80/119)	Energy & Fuels	138	13	3,72%
Environmental Science and Pollution Research	5.190	Q2 (87/279)	Environmental Sciences	120	9	2,58%

Abbreviation: D = number of documents; % = from the sample of documents (N= 349) C= total number of citations

3.3. Authors, institutions, countries and research areas

Table 2 shows the most productive authors in the field, with more than 3 articles published. In addition, their influence is considered regarding total citations. Underscored, was the fact that most of them are working for The University of Manchester, in United Kingdom.

Table 2. Ten most cited authors in the field

R	Author	Organization	Country	D	C
1	Sala, S.	Joint Research Centre (JRC)	Brussels	3	248
2	Azapagic, A.	The University of Manchester	United Kingdom	4	219
3	Cuellar-Franca, R.	The University of Manchester	United Kingdom	3	186
4	Jeswani, H.K.	The University of Manchester	United Kingdom	3	186
5	Slorach, P.C.	The University of Manchester	United Kingdom	3	186
6	Zorpas, A.A.	Open University of Cyprus	Cyprus	4	149
7	Principato, L.	Roma Tre University	Italy	3	140
8	Secondi, L.	University of Tuscia	Italy	3	140
9	Mohan, S.V.	CSIR-Indian Institute of Chemical Technology	India	6	131
10	D'adamo, I.	Sapienza University of Rome	Italy	4	129

Abbreviations: R = rank; D = total of documents published; C = total number of citations

From 349 documents selected, 87.36% and 21.23% is represented and gathered, respectively, showing the 10 most influential countries and institutions. According to the different research areas, as can be seen in Table 3, there is a greater wealth of research related to environmental and technological sciences.

Table 3. Distribution of articles by most influential countries, institutions and research areas

Countries				Institutions			Research areas		
R		D	%		D	%		D	%
1	Italy	79	22.63%	Sapieza University Rome	10	2.87%	Environmental Sciences	180	51.57%
2	United Kingdom	43	12.32%	Council of Scientific Industrial Research CSIR India	9	2.58%	Engineering Environmental	106	30.37%
3	Spain	43	12.32%	University of Milan	8	2.29%	Green Sustainable Science Technology	101	28.94%
4	Peoples R. China	36	10.31%	Hong Kong Polytechnic University	7	2.01%	Energy Fuels	56	16.05%
5	India	22	6.30%	National Research Institute for Agriculture, Food and the Environment (France)	7	2.01%	Environmental Studies	38	10.89%
6	United States	19	5.44%	Parthenope University Naples	7	2.01%	Chemistry Multidisciplinary	28	8.02%
7	Germany	17	4.87%	University of Cantabria	7	2.01%	Engineering Chemical	28	8.02%
8	Brazil	16	4.58%	University of Naples Federico II	7	2.01%	Biotechnology Applied Microbiology	27	7.73%
9	France	16	4.58%	Indian Institute of Chemical Technology IICT	6	1.72%	Food Science Technology	26	7.45%
10	Sweden	14	4.01%	University of Ca Foscary Venezia	6	1.72%	Agricultural Engineering	13	3.72%

Abbreviations: R = rank; D = number of documents; % = from the sample of documents (N= 349)

4. Thematic organisation of the field

4.1. Co-occurrence analysis by Vosviewer software: discovering research hotspots

In a co-occurrence analysis, the links and frequency between keywords help to find the research topics they represent, contributing to comprehending the cognitive structure of a specific field (Börner, Chen and Boyack, 2003) and to locating the hot topics of a research stream (Schildt, Zahra and Sillanpää, 2006).

The VOSviewer output (Figure 3) shows the co-word analysis in the field from 2015. There are 4 clusters grouped by keywords, represented in red, green, blue and yellow. According to the main research focus in the field and considering the strength of the links between the keywords, these clusters are created from a threshold based on the co-occurrence identified by the VOSviewer software. The total link strength measures the strength between the keyword relationship (van Eck and Waltman, 2010). For this case, out of the 349 articles selected, we obtained 2,161 words, with a minimum of 10 occurrences, 44 keywords met the threshold.

Figure 3. Co-occurrence analysis by VOSviewer software

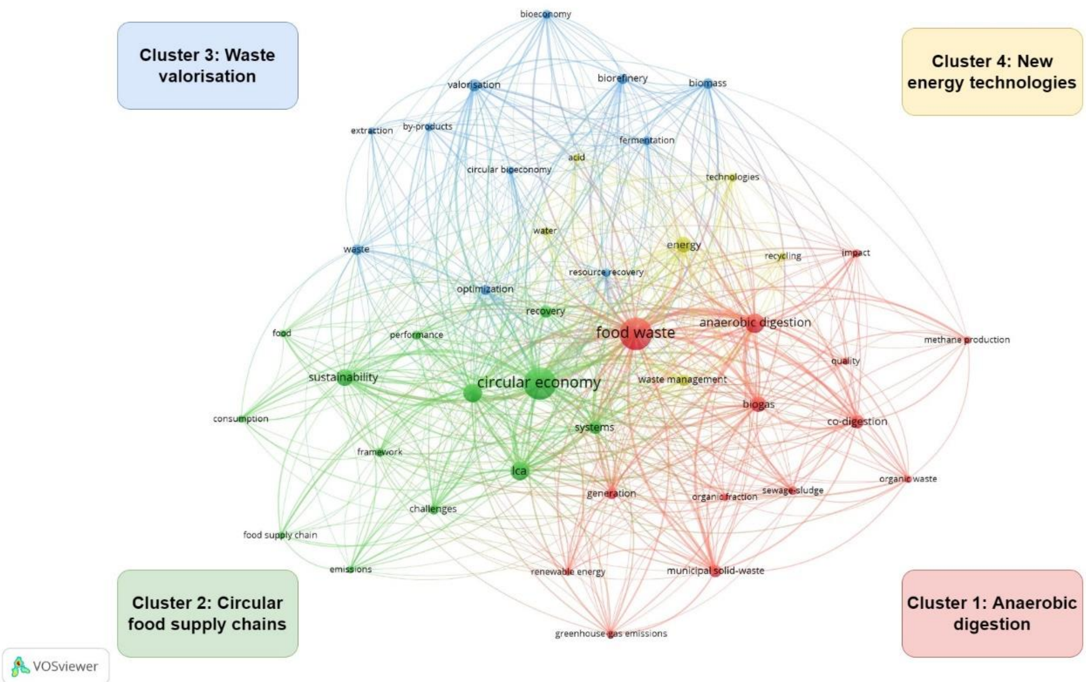
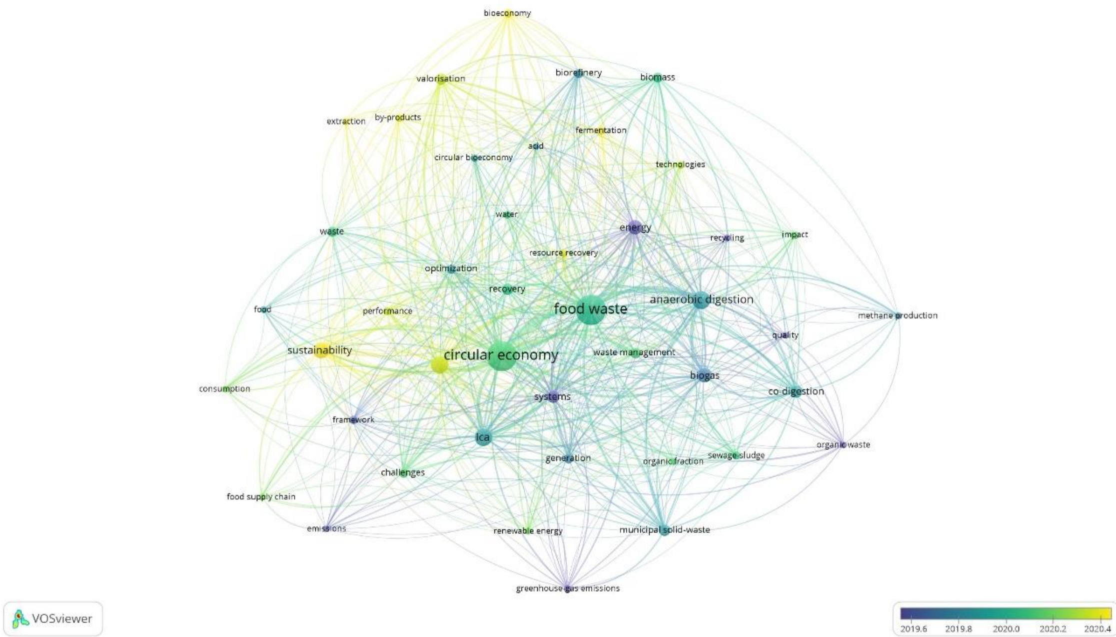


Table 4 has been elaborated to better understand the structure and content of the identified clusters, along with the research trend. It shows clustered keyword information on their occurrences, their average publication year -when the keyword appears- (Figure 4), the average citations of the article that contains the keyword, the number of links -the number of keywords that a keyword co-appears with in a paper- and the total link strength which points the total strength of the keyword links. Additionally, the five most co-occurring keywords are presented.

Figure 4. Overlay visualisation of the co-occurrence analysis by VOSviewer software



4.1.1. Cluster 1: anaerobic digestion

The first cluster in red relates “food waste” to “anaerobic digestion”. Anaerobic digestion is a process of decomposing biodegradable material which releases gases used as energy. The “sewage-sludge” obtained within food waste produces volatile fatty acids that allow the production of biofuels (Battista *et al.*, 2020), eventually generating value from organic waste.

Most of the keywords in this cluster relate to the production of “biogas” by means of “municipal solid waste” in the anaerobic digestion and the “co-digestion” phase. This process is considered for the generation of “renewable energy” -the most recent keyword of this cluster- towards biofuels production such as the biomethane (Paul, Dutta, Defersha and Dubey, 2018) to achieve a reduction of “greenhouse-gas emissions” (Cecchi and Cavinato, 2019).

4.1.2. Cluster 2: circular food supply chain

The green cluster links new sustainable systems in food supply chains applying circular principles. It is fundamental to modify the linear and traditional supply chains models towards "sustainability" -the most common keyword of the analysis-, and circular business systems to improve "performance" and "management". This new framework suggests challenges in consumption patterns (Fogarassy, Nagy-Percsi, Ajibade, Gyuricza and Ymeri, 2020), improving food "recovery" for preventing food surplus and achieving a closed-loop food supply chain (Teigiserova *et al.*, 2020).

In addition, this node pertains to "Life Cycle Assessment" (LCA), an analytical technique for assessing the environmental impacts associated with all stages of a product's life. Researchers have frequently used this methodology to measure the environmental impact of food supply chains (Krishnan *et al.*, 2020).

4.1.3. Cluster 3: waste valorisation

In the blue node, keywords focus on "waste valorisation" linked with the "optimisation" and a "resource recovery" from food waste. The "extraction" process, the most recent keyword of the cluster, is involved in food waste valorisation and biorefinery technology (Zuin, Segatto and Zanotti, 2020; Ebikade, Athaley, Fisher, Yang, Wu, Ierapetritou and Vlachos, 2020). The "fermentation" process is linked to food raw materials in biogas production (Kumar *et al.*, 2021).

The "biorefinery" technology produces bio-based value products via organic waste recycling (Moretto, Russo, Bolzonella, Pavan, Majone and Valentino, 2020). This plays a key role towards "circular bioeconomy". Bioeconomy supports the replacement of fossil carbon with "biomass". Circularity practices in bioeconomy imply the integration of organic waste in processes to adopt stronger sustainable food waste management (Mak, Xiong, Tsang, Yu and Poon, 2020).

Table 4. The major research topics in the field

Cluster 1: Anaerobic digestion						
Keyword	**Occurrences**	**APY**	**AC**	**Links**	**TLS**	**Most co-occurring keywords**
food waste	196	2020.02	17.20	43	685	circular economy (117); anaerobic digestion (51); LCA (40); management (38); sustainability (36)
anaerobic digestion	73	2019.86	20.04	39	322	food waste (51); circular economy (37); biogas (26); energy (19); co-digestion (12)
biogas	44	2019.74	21.80	35	221	food waste (34); anaerobic digestion (26); circular economy (23); co-digestion (17); biogas (12);
co-digestion	33	2019.91	20.39	31	153	food waste (25); circular economy (18); biogas (17); anaerobic digestion (12); energy (9)
municipal solid waste	29	2019.86	22.55	1	136	food waste (18); circular economy (15); anaerobic digestion (14); LCA (12); systems (8)
generation	21	2019.79	22.19	34	96	circular economy (12); biogas (7); anaerobic digestion (3); municipal solid waste (3); energy (3)
sewage-sludge	15	2020.07	15.80	27	69	circular economy (12); food waste (11); co-digestion (8); biogas (4); management (3)
impact	14	2020.14	14.07	21	57	food waste (13); circular economy (8); anaerobic digestion (6); LCA (5); biogas (3)
greenhouse-gas emissions	12	2019.50	21.42	21	59	food waste (7); municipal solid waste (6); LCA (6); systems (5); anaerobic digestion (4)
organic waste	11	2019.45	21.18	20	54	circular economy (9); food waste (7); anaerobic digestion (7); circular economy (6); LCA (4)
renewable energy	10	2020.20	15.00	22	52	circular economy (7); food waste (6); Biogas (7); municipal solid waste (4); LCA (3)

organic fraction	10	2020.11	15.60	19	42	circular economy (6); LCA (4); municipal solid waste (4); co-digestion (4); food waste (3)
methane production	10	2019.80	19.30	15	37	food waste (7); anaerobic digestion (6); co-digestion (5); biogas (4); circular economy (2)
quality	10	2019.60	21.50	16	31	circular economy (6); food waste (5); organic waste (2); generation (2); municipal solid waste (2)
Cluster 2: Circular food supply chains						
Keyword	**Occurrences**	**APY**	**AC**	**Links**	**TLS**	**Most co-occurring keywords**
circular economy	197	2020.10	15.57	42	666	food waste (117); management (48); LCA (42); sustainability (39); anaerobic digestion (37)
LCA	67	2019.87	19.58	40	305	circular economy (42); food waste (40); anaerobic digestion (22); management (18); sustainability (14)
management	67	2020.34	14.90	41	301	circular economy (48); food waste (38); anaerobic digestion (20); LCA (18); recovery (8)
sustainability	55	2020.48	14.95	37	207	circular economy (39); food waste (36); management (15); LCA (14); framework (7)
systems	33	2019.23	16.36	39	157	circular economy (20); food waste (19); LCA (13); anaerobic digestion (10); municipal solid waste (7)
recovery	27	2020.04	15.15	35	105	circular economy (20); food waste (12); management (8); sustainability (5); systems (3)
challenges	18	2020.12	22.78	28	83	circular economy (14); food waste (11); management (8); sustainability (5); framework (4)

performance	17	2020.31	17.41	30	80	food waste (13); circular economy (12); sustainability (5); waste management (4); biogas (4)
framework	16	2019.67	25.06	25	75	circular economy (13); food waste (10); management (9); LCA (4); challenges (4)
emissions	11	2019.64	24.73	20	44	LCA (6); circular economy (5); anaerobic digestion (4); sustainability (4); energy (3)
consumption	11	2020.20	15.55	15	42	circular economy (8); food waste (6); management (5); systems (4); sustainability (4)
food supply chain	10	2020.20	20.00	13	38	circular economy (7); management (3); emissions (3); challenges (3); LCA (3)
food	10	2019.90	18.30	19	33	circular economy (7); sustainability (4); food waste (3); recovery (2); systems (2)
Cluster 3: Waste valorisation						
Keyword	**Occurrences**	**APY**	**AC**	**Links**	**TLS**	**Most co-occurring keywords**
valorisation	29	2020.32	12.28	30	109	circular economy (18); food waste (13); management (8); LCA (7); anaerobic digestion (6)
biomass	23	2020.04	18.04	27	94	food waste (13); circular economy (9); energy (8); anaerobic digestion (7); biorefinery (6)
waste	20	2020.05	18.65	26	58	circular economy (11); management (5); food waste (4); LCA (3); sustainability (3)
biorefinery	18	2019.82	24.67	28	77	food waste (12); circular economy (8); biomass (6); sustainability (4); anaerobic digestion (3)
optimization	18	2019.89	17.00	30	73	food waste (10); circular economy (8); management (5); LCA (5); biogas (4)
bioeconomy	15	2020.43	17.60	22	71	food waste (11); circular economy (8); valorisation (6); anaerobic digestion (6); management (5)

fermentation	15	2020.40	17.33	24	50	food waste (10); anaerobic digestion (5); circular economy (4); biomass (3); valorisation (3)
resource recovery	14	2020.36	15.57	27	61	circular economy (12); anaerobic digestion (4); biogas (4); sustainability (3); energy (2)
by-products	14	2020.36	14.36	21	54	circular economy (7); management (7); food waste (6); valorisation (4); extraction (3)
circular bioeconomy	12	2019.92	21.08	17	33	food waste (7); anaerobic digestion (3); optimization (3); resource recovery (2); fermentation (2)
extraction	11	2020.45	9.82	15	26	circular economy (5); food waste (3); by-products (3); valorisation (3); waste (2)
Cluster 4: New energy technologies						
Keyword	**Occurrences**	**APY**	**AC**	**Links**	**TLS**	**Most co-occurring keywords**
energy	45	2019.51	25.31	37	210	food waste (32); circular economy (27); anaerobic digestion (19); LCA (14); biogas (13)
waste management	26	2020.12	20.62	28	108	food waste (19); circular economy (16); LCA (11); anaerobic digestion (8); energy (6)
technologies	12	2020.27	26.42	27	52	circular economy (8); food waste (7); management (5); anaerobic digestion (3); LCA (2)
water	12	2020.08	14.75	19	39	food waste (6); circular economy (5); management (3); sustainability (3); energy (3)
acid	11	2019.82	9.27	17	27	food waste (4); anaerobic digestion (3); circular economy (2); biogas (2); LCA (2)
recycling	10	2019.20	26.80	17	32	food waste (6); circular economy (5); energy (3); waste management (3); systems (2)

Abbreviations: APY = average publication year; AC = average citation; TLS = total link strength

4.1.4. Cluster 4: new energy technologies

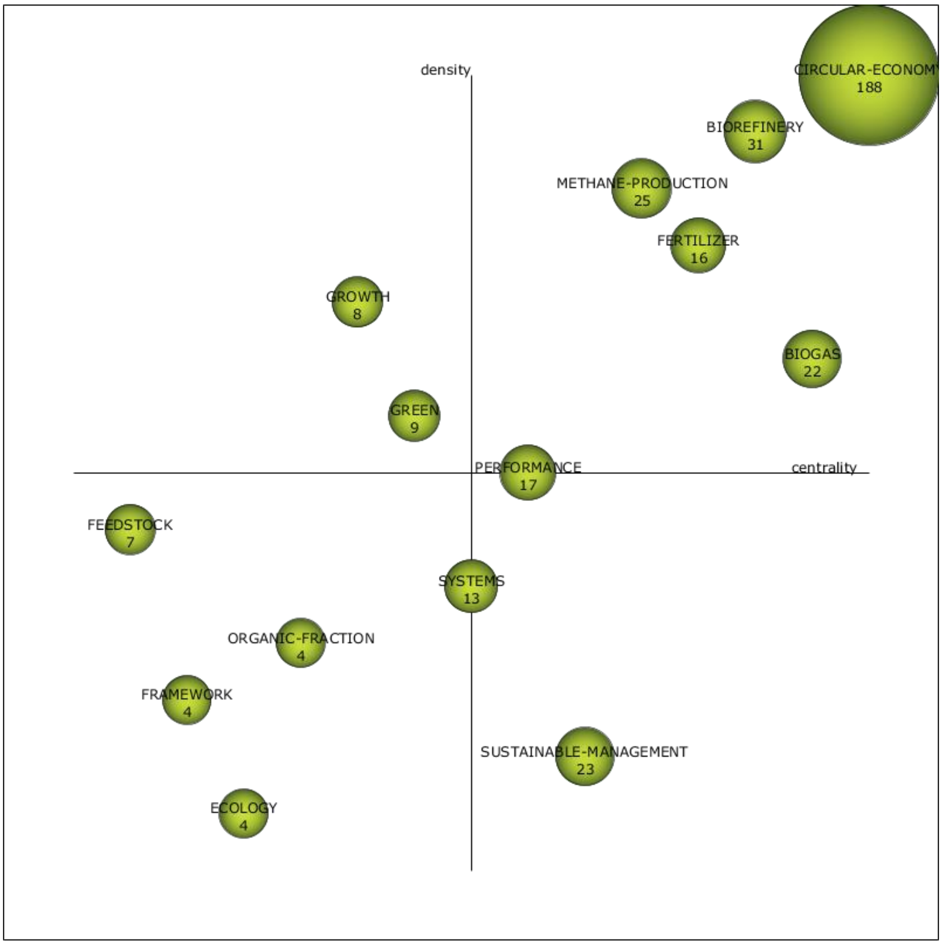
In yellow, the 'new energy technologies' cluster is linked to new "technologies" - the most recent keyword in this group- related to food processes, to obtain renewable sources of energies. The volatile fatty "acids" cultivated from anaerobic digestion to produce biogas in the methane formation enable renewable "energy" based on green chemicals (Tampio, Blasco, Vainio, Kahala and Rasi, 2019).

Waste-to-energy technologies from municipal solid waste enhance a more effective "waste management" by means of "recycling" and waste separation (Istrate, Medina-Martos, Galvez-Martos and Dufour, 2021). Other technologies are focused on wastewater valorisation treatments from waste (Chen, Oldfield, Patsios and Holden, 2020), the use of microalgae as a nutrient source (Sutherland and Ralph, 2021) and the implementation of Industry 4.0 to reduce waste generation towards circular economy business models (Jabbour *et al.*, 2021).

4.2. Co-occurrence analysis by SciMat software: 2020 and 2021 research trend topics

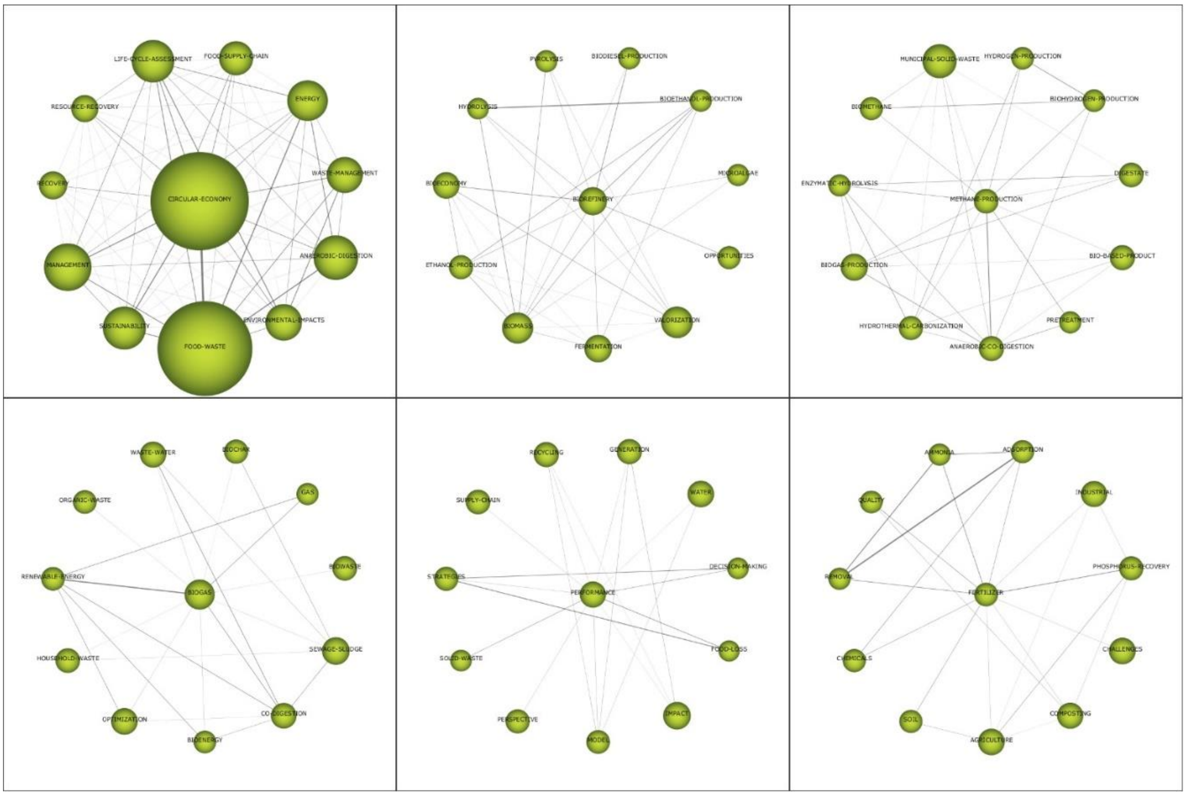
SciMat software (Cobo *et al.*, 2011) displays a strategic diagram of the terms which identifies keywords based on their development and internal cohesion (density) and the relationship with other research topics (centrality). In addition, this software allows one to divide the study into periods. This leads to the classification of the topics into 1) motor themes, 2) basic and transversal themes, 3) more developed and isolated themes, and 4) emerging or disappearing themes (Callon, Courtial and Laville, 1991). This provides an improved understanding of the evolution of the field. As this software also allows the study to be divided into periods, the diagram (Figure 5) was obtained for the last two years (2020-2021).

Figure 5. Strategic diagram per number of documents by SciMat software in Period 2 (2020-2021)



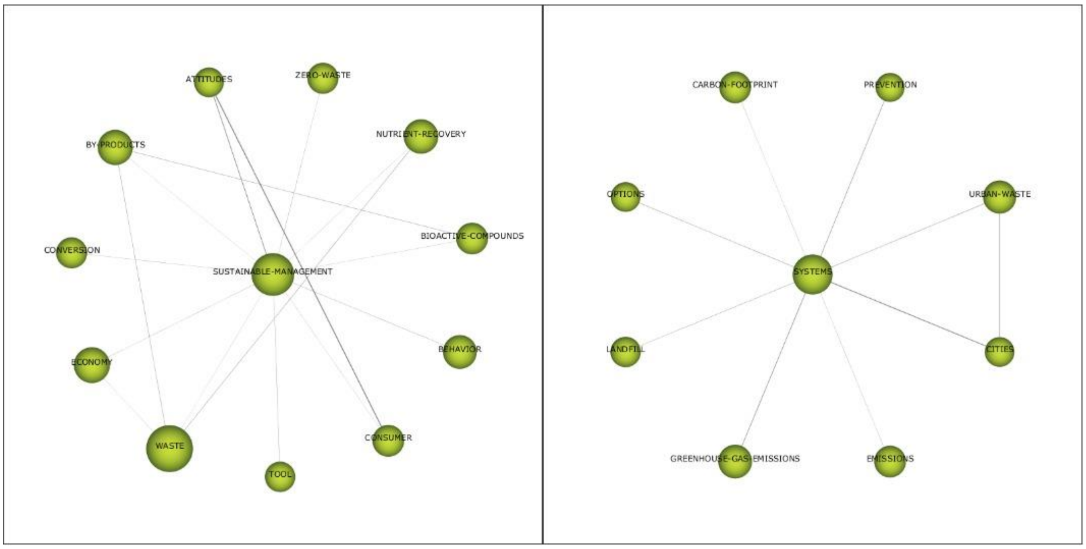
The first motor theme is ‘circular economy’ (Figure 6). It appears with the terms ‘food waste’, ‘anaerobic digestion’ and ‘Life Cycle Assessment’ which suggests it is one of the methodological tools most widely used (Krishnan *et al.*, 2020). The second theme is ‘biorefinery’, which plays a key role in the transition towards circular ‘bioeconomy’. Biorefineries uses ‘biomass’ as a renewable energy resource. The third theme is ‘methane production’, employed in the ‘anaerobic digestion’ with ‘municipal solid waste’ to produce ‘biomethane’ (Martín-Pascual, Fernández-González, Ceccomarini, Ordonez and Zamorano, 2020). The fourth theme is ‘biogas’, obtained from organic waste and widely used as a ‘renewable energy’ in households towards improved waste management (Bedoic, Spehar, Puljko, Cucek, Cosic, Puksec and Duic, 2020). The fifth theme is ‘performance’. This topic sits between a motor theme and basic or transversal theme. Its networks show that the implementation of food waste prevention ‘strategies’ to improve ‘performance’ and ‘management’ is fundamental. Other terms are linked such as ‘recycling’ and ‘supply chain’, in relation to new circular business models (Borrello, Pascucci, Caracciolo, Lombardi and Cembalo, 2020). The sixth theme is ‘fertilizer’, used in the ‘agriculture’ sector. New techniques such as ‘composting’, compost obtained from organic waste, can be implemented following more sustainable and circular practices (Haouas, Modafar, Douira, Ibnsouda-Koraichi, Filali-Maltouf, Moukhli and Amir, 2021).

Figure 6. Motor themes. Thematic subnets: 'circular economy', 'biorefinery', 'methane production', 'biogas', 'performance' and 'fertilizer'



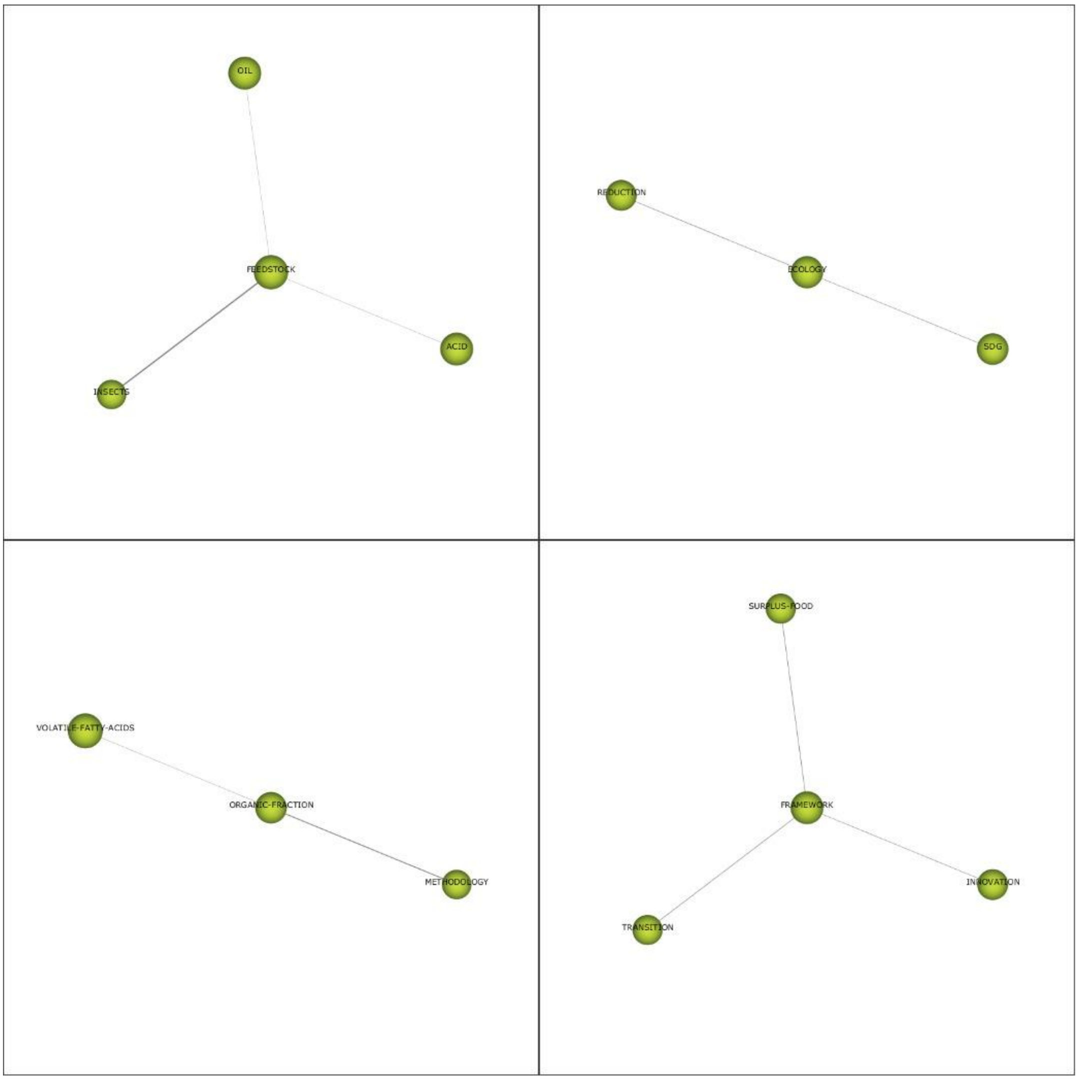
‘Sustainable management’ appears as a basic and transversal theme (Figure 7). This is linked to ‘consumer’, ‘behavior’ and ‘attitudes’. Whilst ‘systems’ is between a basic, transversal and emerging theme. Studying the subnets, we can observe the link between 'urban waste' and 'cities' and their relationship between 'greenhouse-gas-emissions' and 'carbon footprint'.

Figure 7. Basic and transversal themes. Thematic subnets: 'sustainable management' and 'systems'



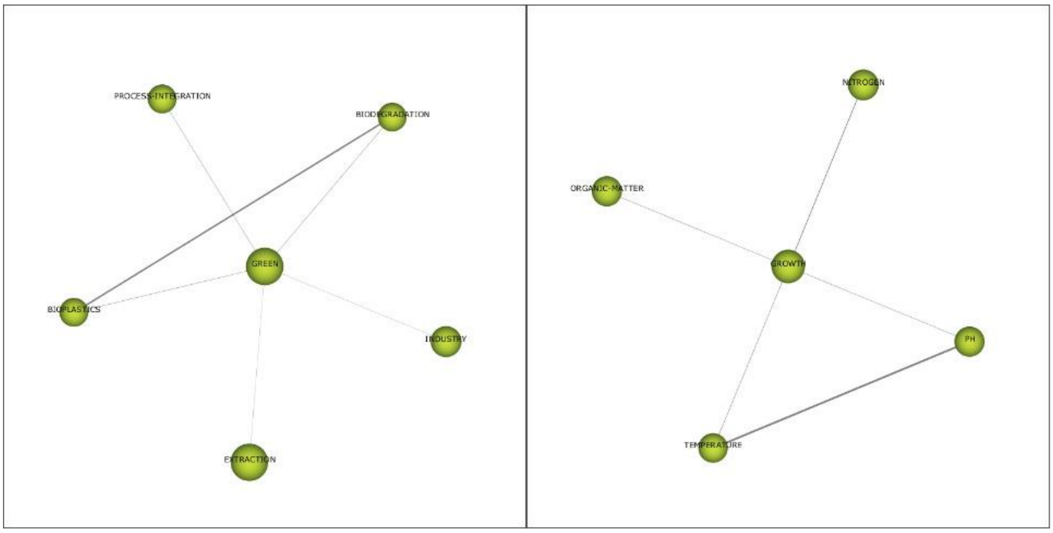
Between the emerging themes (Figure 8) we obtained the terms 'feedstock', which it is highly linked to insects as a raw material. 'Ecology' related to 'SDGs' and 'reduction', one of the 3Rs principles, connected to circular economy. 'Organic fraction' which is used in composting and associated with 'volatile-fatty-acids' from food waste. And 'framework' related to 'surplus-food' and the required 'transition' to a more sustainable and circular models.

Figure 8. Emerging themes. Thematic subnets: 'feedstock', 'ecology', 'organic fraction' and 'framework'



‘Growth’ is an isolated theme related to ‘nitrogen’ and ‘ph’ involved in ‘organic-matter’. ‘Green’ is a more developed theme associated with ‘bioplastics’ and ‘biodegradation’ in the food industry, moving towards circular and sustainable business models (Figure 9).

Figure 9. Developed and isolated themes. Thematic subnets 'green' and 'growth'



5. Discussion and research agenda

Following the co-occurrence analysis and clusterisation, this section presents a discussion to establish an interpretation of the results and sets out lines of development for a research agenda.

5.1. Discussion

The word "2030 Agenda” doesn´t appear in any of the clusters analysed. This absence is remarkable considering the fact that the 2030 Agenda underscores food waste management as a key part of achieving several of its objectives. SDGs are mentioned, yet as an emerging issue. In light of this, Priyadarshini and Abhilash (2020) point out the lack of implentation in waste management. Is research taking place in isolation from the full achievement of the SDGs?

The analysis of the results demonstrates the absolute weight of the technical and process concepts in the research. It should not be forgotten that the operation of new procedures is conditioned by social and cultural aspects. Research in new technologies focuses on the different processes that allow renewable and sustainable energy to be obtained from organic matter within the food chain. Although this is undoubtedly a field of great application and usefulness for various sectors, technological development must cover new requirements, such as the need for deeper relationships with suppliers and customers and greater traceability. Is research accompanying realities in the sector such as the application of Artificial Intelligence and Blockchain in food waste management?

Sustainable management is related to consumer behaviour and attitudes. Consequently, stakeholder training and awareness-raising is essential (Leipold, Weldner and Hohl, 2021; Börühan and Ozbiltekin-Pala, 2022) to coin the term "circular society" in the field of waste management. To encourage circular consumer behaviour, factors such as process and packaging design improve food recovery (Teigiserova *et al.*, 2020).

One of the topics attracting most attention from researchers is the circular bioeconomy in sustainable food waste management (Mak *et al.*, 2020). This new paradigm supports the substitution of fossil carbon with biomass for food, feed and energy supply. The incorporation of nutrients from food waste into animal and farm feed is a significant environmental improvement and generates wealth and employment opportunities.

5.2. Research agenda to achieve a circular management of food waste

The first proposal of the research agenda would be related to the *application of SDGs to the improvement of food waste management from social and educational angles*. With less than eight years to the deadline set by the 2030 Agenda, the related research should be further developed and more closely linked to the other CE principles and their social and economic aspects.

The second proposal is associated with the *need for more research into aspects beyond the environment and technical and technological development*. A better understanding of the new characteristics of circular relationships needs to be established with a wide range of stakeholders (Moggi and Dameri, 2021). Deeper and more frequent relationships are required, as they are key to the successful implementation of circular economy principles (Dora, 2020).

Awareness-raising, although a necessary condition, is no longer sufficient. Institutional and regulatory support is needed to implement circular waste management for both companies and consumers (Närvänen *et al.*, 2021). The third proposition is based on the *creation of a regulatory or normative framework supported by the institutions* and allowing for the encouragement or penalisation of certain actions. Taxation policies for example, could help to discourage food waste, which would contribute to improving individual food waste behaviour (Ang, Narayanan and Hong, 2021). It should also contemplate new realities such as data processing or access to certain information. The use of tools within the framework of the Internet of Things or the management of information through Big Data would facilitate the design of strategies and decision-making (Velvizhi *et al.*, 2020). This will require further research at the technological level, while considering regulatory adjustments to establish the rules of the game.

Thus, quantification with direct or indirect measurements could be carried out. The fourth line of a future research should consider *the need for waste measurement differentiating*. Researchers have frequently used "Life Cycle Assessment" (LCA) in measuring the environmental impact of food supply chains (Krishnan *et al.*, 2020). Further exploration of other measurement alternatives would allow for a more comprehensive measurement framework. Compared to direct measurements, which are more complex, yet at the same time more reliable. Indirect measurements require different quantification approaches with various actors to achieve greater precision (Corrado and Sala, 2018).

The fifth and last of the proposals on the research agenda relates to measurement constraints. Concepts must be *measured by considering both the context in which they are produced and the interrelationships between them*. The interpretation and measurement of these terms will be conditioned by the context in which they occur (D'Adamo, Falcone, Huisingh and Morone, 2021). There are interrelationships between the concepts studied that need to be considered. Improved waste management would have a positive effect on solving other issues such as food loss (Kibler, Reinhart, Hawking, Motlagh and Wright, 2018).

6. Conclusions

To achieve food waste management in a more sustainable method, breaking with the inefficient linear model used up to now, numerous recent studies have analysed food waste management related to the circular economy. This study presents the cognitive structure of food waste management with the circular economy in a broader sense; providing information on the state of academic contributions and the links between the two topics.

Despite initial research on the topic in 2015, interest continues to rise, with more accelerated growth from 2018. The period 2018-2021 stands out, with research doubling compared to the previous year (RQ1). The results reveal that journals in environmental sciences are the most representative. No journal in the social sciences is among the most cited, although the most influential author, Serenella Sala, interestingly belongs to this area. Regarding institutions, The University of Manchester is the most influential (RQ2). The main research topics are related to the recovery processes of food waste towards the conversion into renewable and cleaner materials or energy sources (RQ3). To respond to RQ4, a discussion and a research agenda has been established that has important theoretical and practical implications.

6.1. Theoretical contributions

In terms of theoretical or academic implications, this study represents a new perspective on previous bibliometrics in the field of food waste management by bringing three contributions: 1) The incorporation of the circular economy from a holistic approach compared to previous papers, which focused on more specific aspects of this paradigm. 2) the use of two complementary software -VOSviewer and SciMat- to a better understanding of the research topics evolution. In this way, SciMat displays a strategic diagram based on its density and centrality. In addition, the results obtained in SciMat make it possible to validate the VOSviewer results. Hence, the clusterisation performed by VOSviewer as the most recent keywords, e.g. ‘sustainability’, coincide with the topics considered as emerging in SciMat such as ‘sustainable management’. 3) The scarcity of research coming from the social sciences means incorporating areas of knowledge such as management, law, psychology or anthropology is essential. The theoretical framework in future research should be enriched with different perspectives or areas of knowledge to achieve successful implementation of circular economy principles in food waste management.

6.2. Practical contributions

Linked to these aspects, it also offers practical implications. Companies must manage stakeholder expectations and evaluate their sustainability efforts (León Bravo, Moretto and Caniato, 2021). Therefore, it also affects all supply chain actors and requires their involvement for the operation of circular procedures and techniques (Despoudi *et al.*, 2021). However, two additional aspects should be considered. On the one hand, the need to create a regulatory and support framework held by institutions at different levels (Närvänen *et al.*, 2021). On the other hand, firms need to establish indicators to measure both the level of circularity development in waste management and the compliance with the settled objectives (D'Adamo *et al.*, 2021).

6.3. Limitations and future research lines

This paper is not free of limitations. Relying solely on one database -WoS- implies the exclusion of papers that are useful for the study (Secinaro, Calandra, Lanzalonga and Ferraris, 2022). Articles written in English only have been considered in this paper, meaning there is scope for greater insights in publications of other languages. In addition, the interpretation of the co-word analysis maps visualised by VOSviewer has a subjective component that cannot be ignored.

Future research lines can focus on monitoring the evolution of the topics to check whether the emerging topics are finally consolidated and whether new relationships are established between the terms. The creation of databases with relevant information for research on food waste would facilitate the development of new research and requires both public and private cooperation. Additionally, a replication of this study with a focus on food loss would allow a comparison with the present study. This would facilitate a better understanding of how to improve the application of circularisation principles throughout the food supply chain.

Finally, empirical works need to be extended to other food products (Krishnan *et al.*, 2020), other geographical areas (Battista *et al.*, 2020), other context (Hebrok and Heidenstrom, 2019) and comparisons between different companies (Kazancoglu, Ekinci, Mangla, Sezer and Kayikci, 2021).

Food waste management is a complex phenomenon that can be facilitated by the application of circular economy principles. However, achieving circular food waste management requires complementing the extensive technical and technological knowledge already achieved, with knowledge from the social sciences.

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CONCLUSIONS

CONCLUSIONS

Circular economy is a concept of relevance to achieve sustainability according to the economic, environmental and social pillars (Murray, Skene and Haynes, 2017). Its application in the different polluting industries through their supply chains is essential to protect natural resources. In recent years, research on this topic has gained special interest, thanks in large part to the new environmental and economic legislation applied in different regions and countries. The transition towards a circular economy approach supposes a challenge for organisations, institutions, governments and citizens.

The circular supply chain implies cooperation and coordination between the stakeholders to achieve the regeneration, restoration and recovery of raw materials, seeking to reduce harmful effects on the environment (Govindan, Mina and Alavi, 2020). Highlighting the importance of networks between suppliers and customers. This circular issue is scarcely studied in the scientific literature. For this purpose, this doctoral thesis aims to fill this gap in the literature by means of an empirical analysis (article 1), a systematic literature review (article 2) and a bibliometric analysis (article 3). Results obtained offer opportunities for the circular economy principles implementation, indicating the advantages and possibilities for its application, complementing existing research in the literature.

The first article shows that knowledge management plays a key role in circular supply chains implementation. Results show that firms with well-managed knowledge flows have a greater productivity and efficiency, which makes them more competitive and affect to their innovation capacities (Abbas, 2020).

Circular systems achieve lower environmental negative impacts because of a lower consumption of resources and materials (Hazen, Overstreen, Jones-Farmer and Field, 2012). This new sustainable and circular production paradigm implies new design of products and processes and stakeholders' network, underscored customers' awareness. For this purpose, it is essential that different agents have an alienated and integrated vision to optimise synergies and the flow of knowledge. Acceptance and cooperation between actors involved in the supply chain is key in the transition to circular business models (Ellen MacArthur Foundation, 2013). Highlighting that the main issue in circular economy application is the production cost associated (Zou, Wang, Deng and Chen, 2016).

Sustainable and circular strategies could improve the supply chains resilience (Miceli, Hagen, Riccardi, Sotti and Settembre-Blundo, 2021). This transition towards a circular economy implementation suppose a challenge at technological, relational and production level. The establishment of new tools and routines is required, to facilitate a new knowledge flow (Alonso-Muñoz, González-Sánchez, Siligardi, García-Muiña, 2021). Thanks to cooperation and collaboration, the external capital is essential to firms to support their capabilities in the whole supply chain. These relationships are affected by the circular principles, taking a more active and greener role in the processes involved. This implies the design of new networks between stakeholders that provide a higher efficiency, effectiveness, and resilience (Muñoz-Torres, Fernández-Izquierdo, Rivera-Lirio, Ferrero-Ferrero, Escrig-Olmedo, Gisbert-Navarro and Marullo, 2018).

The conceptual model proposed in the second article considered the relevance between the customers-suppliers' relationships and the implementation of circular supply chains. The first proposition is focused on support and share knowledge with suppliers and customers and the supply chain intelligence integration. On the one hand, the greener and sustainable election of suppliers are considered: linked to the Industry 4.0 according to the intelligence transport and greener logistics and how can affect to circular networks. Regarding to the supplier election, the third proposition suggested the importance of multicriterial tools and ethical codes. The improvement of the suppliers' engagement due to active participation, assistance and rewards is presented as the fourth proposition.

On the other hand, customers behaviours, awareness and acceptation are also outlined. Firstly, associated to the acceptability with refurbished and remanufactured products, and how additional services and warranty policies can positively affect to circular networks. Secondly, is exposed that the customers participation in product recovery is increased by means of discounts, rewards, and environmental education, which positively affects to circular networks in the supply chain.

Article three provides the intellectual and cognitive structure of the circular food waste management considering a broader approach. This field has been gained momentum for academics and practitioners. This work underscored the characteristics of the literature published on the research field, the main areas of knowledge and the most studied topics. Trends in circularity and food waste are analysed, offering future lines of research in the field, which may be useful to academics. Highlighting the following themes: 1) food waste recovery by the use of anaerobic digestion process and biogas production for the generation of renewable energy (Paul, Dutta, Defersha and Dubey, 2018); 2) the transition towards circular food supply chains, and its linkage to Life Cycle Assessment technique (Krishnan, Agarwal, Bajada and Arshinder, 2020); 3) the required food waste valorisation, the use of biorefineries and circular bioeconomy practices; and finally, 4) the implementation of industry 4.0 and waste-to-energy biotechnologies focus on waste separation and wastewater treatments.

I. Theoretical implications

This doctoral thesis incorporates academic contributions about circularity in supply chains. The first article focused on the exploitation dimension, uses the absorptive capacity framework -due to the significance of technological and market knowledge-, closely linked to the final consumer in the supply chain. This work considers a new approach of the design of processes and products, where new smart technological tools are fundamental in the transition towards a circular supply chain. The relationships between customers' behaviour and their acceptance of circularity, and the industrial symbiosis association with the optimisation of the knowledge flow is also taken into account. Highlighting that cooperation between supply chain agents, and communication, is key to implement the circular economy.

The second article highlights the lack of published studies that link circularity to supply chain relationships (Farooque, Zhang, Thürer, Qu and Huisingh, 2019). There are previous studies published in the current scientific literature that link sustainability to intellectual capital (Minoja and Romano, 2021), but they not specifically associate the external capital to circular economy principles. This dissertation fills the gap in the literature regarding circular customer-supplier relationships from an external capital perspective -following the intellectual capital-based view theory-. In this regard, from a theoretical point of view, this thesis provides a framework for research, as a guiding point on relationships in circular supply chains.

The third article also presents academic implications, carrying out a bibliometric analysis that use two complementary software that validates both analysis results: VOSviewer and SciMat. This work is focused on a holistic approach, in contrast with previous bibliometrics published in the field. Additionally, it should be noted that exists a lack of social sciences research related with circular food waste management, which suppose the necessity of its incorporation to enrich the circular economy implementation in the food system.

II. Practical implications

The doctoral thesis presents practical contributions for practitioners, organisations, governments, and citizens. The first article highlights that it is required a circular economy principles guideline for practitioners. It is essential to institutionalise circular supply chain management implementation based on the innovative performance focused on knowledge. This work shed lights about new and smart technologies that favour to supplies management in the optimisation of energy consumption and recycling, by means of facilitating the operational procedures for product designing, monitoring and logistics. Supporting the use of new and smart technologies and its relevance in exploiting external knowledge for radical innovations. In addition, the development of a relational capacity is fundamental. The higher the level of commitment between stakeholders, the greater the flow of knowledge and resources is (Murray *et al.*, 2017).

It is required a bidirectional knowledge flow linked to educational and communication aspects, considering that majority of firms ignored the social issue in their sustainability policies. Organisations via marketing tools can influence in the customers behaviours, affecting in their consumption patterns and engaging with circularity principles (Azevedo, Godina and Matias, 2017).

The knowledge flow can be facilitated thanks to the establishment of new routines focused on both new logistics and production technologies knowledge, and customer knowledge, to obtain novel products from a circular economy perspective. This study support the use of smart and new technologies and their relevance for radical innovations based on exploiting external knowledge. Education and communication can optimise customers' knowledge flows, by means of a bidirectional knowledge flow focused on the implementation of the circular economy.

The exploratory model proposed in the second article provides a framework for the organisations' relationships with suppliers and customers following the circular economy principles. Hence, this will be useful for organisations in the current context marked by successive crises to adopt a more sustainable and circular commitment (Wu, Huo, Yu and Zhang, 2020).

Additionally, this thesis implies practical contributions for governments to achieve a transition to the circular economy, emphasising the need for greater efforts at the public-private level in cooperation with organisations to achieve this paradigm shift. Stressing the need for policies not only oriented to recycling (Ghisellini, Cialani and Ulgiati, 2016).

It is necessary to develop complementary tools to improve customers' acceptance and confidence in remanufactured and refurbished products. This supposes implications for citizens, highlighting the need to change their consumption patterns, behaviours and awareness towards circular practices. Customers are affected by information and training programs, which can modify their consumption patterns towards sustainability behaviours (Mokhtar, Genovese, Brint and Kumar, 2019). Thus, the use of complementary services, discounts, and warranties are essential to adapt this new circular consumption models (Taleizadeh, Alizadeh-Basban and Akhavan Niaki, 2019). Furthermore, a close relationship with customers is required, which involve a greater trust with suppliers. The establishment of support services and standards are essential to circular economy principles adoption (Mokhtar *et al.*, 2019). Regarding to suppliers' selection, ethical codes and multicriteria techniques ensure a more circular and sustainable supplier (Salvioni, Astori and Cassano, 2014).

The third article's practical implications are focused on stakeholders required involvement in the whole supply chain towards achieving circularity (Despoudi, Bucatariu, Otles and Kartal, 2021). The current food and economic crisis required a transition towards new consumption patterns to reduce food waste. Introducing circular principles -mainly based on recycling and reuse- in the food supply chain management can facilitate the control about processes in all the stages, reducing costs, increasing efficiency and the food system security (Närvänen et al., 2020). Moreover, circular food systems can enable Sustainable Development Goals achievement, following the SDG 12.3 that points the relevance of reduce food waste and food loss (United Nations, 2015) which can be reach by means of food recovery, reuse and recycling actions.

In addition, measurement indicators are essential to evaluate, firstly, the compliance with the sustainable-circular issues and circular development; and secondly, the necessity of a regulatory framework required for institutions (Närvänen, Mattila and Mesiranta, 2021).

III. Limitations and future research lines

The present doctoral thesis is not exempt from limitations, which can be considered as future research lines of analysis to be improved in future studies in the field.

Circular economy implementation, the application of its principles in the different stages of the supply chain and the incorporation of circular practices in different industries suppose a constantly evolving topic. Therefore, this doctoral thesis presents several lines of future research, which are exposed below:

The first article discusses the options to expand and enrich the study by using primary sources of information and analysing different marketing tools, and their relation to innovation performance. Considering different types of technologies and market-related routines. This work focus on direct relationships between variables of the exploitation phase, not considering other phases of the absorptive capacity, for instance, the effect of investment in R&D, which could be considered for further research in the field.

There are previous studies that link intangible capital with sustainability, but not mainly direct with circularity. The article 2 solely relies on external capital application, considering suppliers and customers relationships in the supply chain, more targeted on technological and operational processes. For this reason, future studies can focus on the human capital, internal or organisational capital and external capital joint effect. Moreover, empirical evidence and the application in particular industries, such as the automotive or the textile sector, could be address.

In further research, other databases for bibliometrics analysis can be used to not exclude potential useful papers, -the main limitation of this study-, in addition to the exclusively consideration of articles published in English. Also, other bibliometric techniques, such as co-authorship can be considered, to complement the methodology used in this thesis, regarding to article 3. In addition, tracking the topics evolution to evaluate future emerging topics and relationships between new practices can of interest. Expand the analysis to other stages of the food system -such as food loss- can complement the present study and help in the understanding of the circular food supply chain implementation.

Public and private cooperation is key towards a required food waste database, that host significant research information collected for scholars, institutions and practitioners. With emphasis on the importance of working within a regulatory and legislative framework related to circular food supply chains, from a multidisciplinary approach. And the relevance of developing measurements and standards on circularity in different sectors, which is not widely studied, and it requires for further research.

Special attention needs to be paid to empirical works. More comparative studies between different organisations, geographical areas and food products are needed (Kazancoglu, Ekinci, Mangla, Sezer and Kayikci, 2021). In future research could be interesting to amplify bibliometric studies linking circular economy or circular economy supply chains to alternative sectors, such as construction and demolition, textile and garment industry, electrical vehicles industry, and tourism sector, among others. Complementing the bibliometrics already studied and published in the scientific literature.

In addition, supplementary methodologies than those applied in this doctoral thesis can be used, as established in articles 1, 2 and 3, and complementing this work using other tools and techniques. In the first article, a comparison carrying out a case study analysis can be conducted, to identify other dimensions for both technological and market knowledge. The second article can be complemented by an empirical study considering the suppliers-customers networks in a particular industry, such as the textile. In the third article, further bibliometric analyses could be carried out using new tools such as HistCite, Pajek, BibExcel or InCites, among others, to complement the results obtained in this doctoral thesis. Moreover, other bibliometric techniques can be used, such as co-citation and bibliographic coupling.

Further studies that specifically focus on cleaner energy production by means of food waste, thanks to biorefineries, anaerobic digestion and waste-to-energy and its effective application in organisations are required (Germar, Soler and Sánchez-Teba, 2021). Underscored, the need of food waste valorisation indicators and policies providing a reference framework for scholars, practitioners and institutions.

Similarly, an interesting aspect to be addressed is to analyse the linkage between renewable energy technologies towards circular economy implementation. Considering the current energy situation, it is needed a change of paradigm for a more ecological energy production and consumption, in which circular economy is key. The use of greener energies, such as biomass, can decrease fossil fuel consumption and CO_2 emissions, the major greenhouse gasses contributor (Dar, Hameed, Huo, Sarfraz, Albasher, Wang and Nawaz, 2022). Thus, circular economy can play a pivotal role towards a cleaner energy transition based on new models to prolong the value chain, which may provide a future research opportunity (Su and Urban, 2021).

IV. References

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