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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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Citation: Alonso-Muñoz, S.; González-Sánchez, R.; Siligardi, C.; García-Muiña, F.E. Building Exploitation Routines in the Circular Supply Chain to Obtain Radical Innovations. *Resources* **2021**, *10*, 22. https://doi.org/10.3390/resources10030022

Academic Editor: Kazuyo Matsubae

Received: 31 December 2020
Accepted: 28 February 2021
Published: 4 March 2021

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).

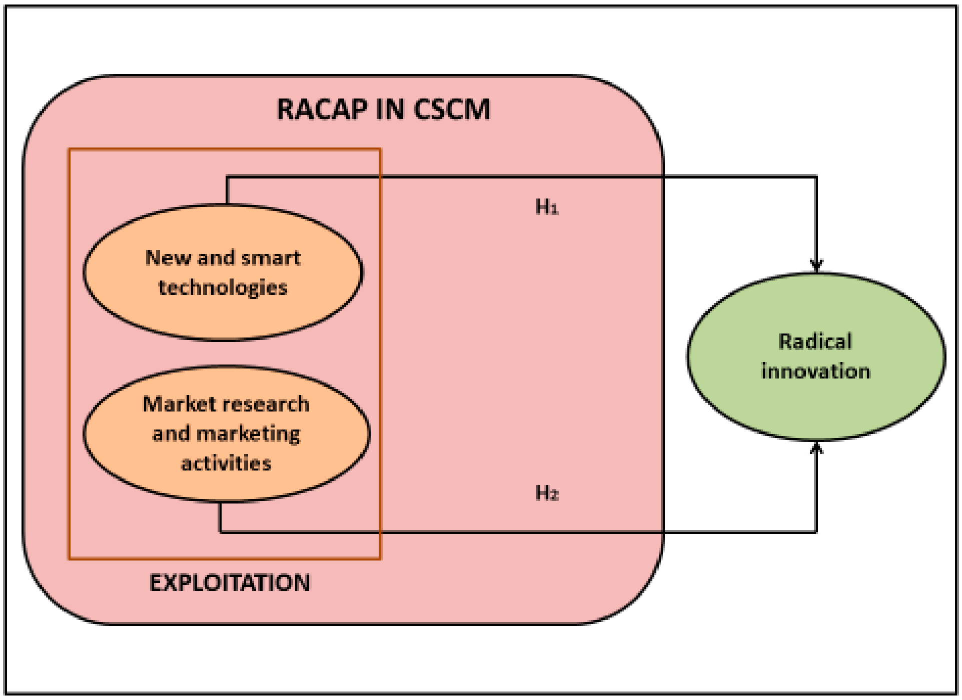

Figure 1. Model of analysis.

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.

Author Contributions: Conceptualization, R.G.-S. and S.A.-M.; data curation, C.S. and F.E.G.-M.; formal analysis, R.G.-S. and C.S.; investigation, R.G.-S. and F.E.G.-M.; methodology, R.G.-S. and F.E.G.-M.; supervision, R.G.-S. and F.E.G.-M.; writing—original draft preparation, S.A.-M. and R.G.-S.; writing—review and editing, S.A.-M. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the European Union under the LIFE Program, grant number: LIFE16ENV/IT/000307 (LIFE Force of the Future).

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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 operations	Sig. (bilateral)	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000			
		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 market	Sig. (bilateral)	0.000	0.101	0.000	0.003	0.000	0.000	0.000	0.000	1.000		
		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 innovation	Sig. (bilateral)	0.000	0.007	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.000	
		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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