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The integration of circular economy and digital transformation as a catalyst for small and medium enterprise innovation

Marta F. Arroyabe[1] | Carlos F. A. Arranz[2] | Juan Carlos Fernandez de Arroyabe[1]

[1]Essex Business School. University of Essex, Elmer Approach, Southend-on-Sea, UK
[2]Greenwich Business School. University of Greenwich, Old Royal Naval College, London, UK

Correspondence
Marta F Arroyabe, Essex Business School. University of Essex, Elmer Approach, Southend-on-Sea, UK.
Email: mf17255@essex.ac.uk

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Abstract

This study examines the integration of digital and circular economy (CE) strategies in small and medium enterprises (SMEs) and their impact on innovation. The research uses data from the Eurobarometer survey conducted by the European Commission, which includes a sample of 16,365 SMEs. Using a combination of regression analysis and machine learning tools, the results indicate that a high degree of digitalisation within SMEs enhances the integration of a CE orientation. However, it is not necessary for SMEs with advanced CE orientations to have high levels of digitalisation. Additionally, the study finds variability in the integration of digital and CE orientations among SMEs, identifying four distinct groups of companies with differing levels of compatibility. Moreover, SMEs that successfully integrate both digital and CE orientations are more likely to innovate, whereas those with poor integration exhibit a lower probability of innovation. These findings offer crucial insights for managers and policymakers aiming to bolster SME innovation, digitalisation and sustainability. The research underscores the need for a balanced integration of digital and CE orientations to enhance innovation and environmental impact in SMEs.

KEYWORDS
CE, digitalisation, innovation, SMEs, strategic orientation

1 | INTRODUCTION

In the contemporary landscape of business and technology, two pivotal trends have emerged as driving forces: the circular economy (CE) and digitalisation. The CE model, rooted in the fundamental objective of harmonising economic growth with environmental preservation, champions innovative approaches that underpin sustainable production and consumption (Bocken et al., 2017; Ferasso et al., 2020; Geissdoerfer et al., 2017; Ghisellini et al., 2016; Pieroni et al., 2019; Rodríguez-González et al., 2023). Central to CE is the intricate processes of regeneration and restoration, manifesting through closed loops and the artful combination of reuse, renewal, remanufacturing and recycling methodologies (Katz-Gerro & López Sintas, 2019; Perey et al., 2018; Rosa et al., 2019). Simultaneously, the digital revolution has permeated societies, reshaping economies, communication paradigms, job structures and the very skills essential for both the workplace and daily life (Guandalini, 2022; Amankwah-Amoah et al., 2021; Blackburn et al., 2022; Dabrowska et al., 2022; Di Vaio et al., 2020; George et al., 2020; He et al., 2020). As industries adapt to this digital age, production, innovation and the very fabric of industrial organisation undergo transformational shifts (Ciarli et al., 2021; George et al., 2020; Urbinati et al., 2020; Brivot

Abbreviations: ANN, artificial neural networks; CE, circular economy; CMB, common method bias; CMV, common method variance; MLP, multilayer perceptron; SMEs, small and medium enterprises; TAM, Technology Acceptance Model; TPB, Theory of Planned Behaviour.

et al., 2014). At the intersection of these societal and technological revolutions lies the aspiration to integrate the 'green' ethos of the CE model with the digital essence of modern technology within the framework of enterprises (Huettel et al., 2022; Guandalini, 2022; Hellemans et al., 2022; Rusch et al., 2022).

In this context, the research has not been aliened to the integration of CE and digitalisation in companies. In particular, there is an important research question that deals with how these two trends affect the innovation of companies. That is, while there is a consensus in the literature that the implementation of CE models brings about the development of eco-innovation and that digital transformation facilitates both process and product innovations in companies (Ardito et al., 2021; Ghobakhloo, 2020), however, there is a gap in the research on how the integration of both strategies affects the innovation of companies, finding contradictory arguments in the literature. On the one hand, some studies have highlighted the complementarity of both strategies in the innovation process. For instance, Vial (2021), Verhoef et al. (2021) and Kunkel and Matthess (2020) highlight the role of digital technologies and how they can promote sustainable consumption behaviour and waste management and optimize energy consumption. In this line, Rodríguez-González et al. (2023), Bag et al. (2020) and Santoalha et al. (2021) point out that digital technologies facilitate environmental innovations, promoting the implementation of circular economy models and minimising waste. On the other hand, some studies indicate the difficulties of integrating both trends, from the point of view of resources and company management, which brings a negative effect on the innovation of companies (Ardito et al., 2021; Sharma et al., 2020). For example, Ardito et al. (2021) point to the possibility of a negative interaction between these two trends; especially, this is produced in the case of small and medium enterprises (SMEs), where company resources are severely limited, and corporate decisions to digitalize and environmental sustainability may be conflicting. Moreover, SMEs have a limited number of employees, so following both digital and environmental directions can expose employees to a variety of tasks and skills, creating a dispersion of effort as consequence of the diversity of activities and different objectives. Ardito et al. (2021) and Ocasio (2010) conclude that this limitation of resources is a negative argument in the innovation of companies.

This research bridges this critical knowledge gap by investigating the dynamic interplay between digital transformation and CE, and how it affects the innovation of SMEs. This research is particularly important considering that SMEs contribute significantly to environmental issues, accounting for approximately 60 to 70% of industrial pollution in Europe, especially in the manufacturing sector (Madrid-Guijarro & Duréndez, 2024; OECD/ERIA, 2018). For instance, Dey et al. (2022) noted that manufacturing SMEs alone are responsible for 64% of air pollution, yet a mere 0.4% have implemented environmental management programs. Regarding the digitalisation in SMEs, data from 2021 reveals that only 55% of SMEs in the EU attained a basic level of digital intensity, contrasting with 88% of large enterprises (European Commission, 2023). Moreover, merely 3% of SMEs achieved a very high level of digitalisation. This performance notably diverges from the EU's Digital Compass objective, which targets over 90% of SMEs to reach at least a basic level of digital intensity by 2030 (European Commission, 2023).

In this investigation, we will use the EU database (Flash Eurobarometer 486, 2020), which includes 16,365 SMEs. Moreover, we utilize the strategic orientation perspective as our theoretical framework (Narver & Slater, 1990). Departing from prior static analyses, our research embraces the dynamic nature of this integration, recognising the varying levels of digital and CE integration within companies. The strategic orientation perspective allows us to conceptualize both digitalisation and CE as strategic orientations of SMEs, setting the stage for a nuanced exploration of their integration dynamics (Roxas & Coetzer, 2012).

From a methodological point of view, we will combine regression analysis with machine learning, using artificial neural networks (ANNs) and cluster analysis in our modelling. This strategic combination of statistical methods offers several substantial advantages. On one hand, it enables us to explore causal relationships between variables, which is essential for understanding the underlying dynamics. Thus, to the explanatory power of regression models, we can add the capacity of ANNs in the analysis of complex problems, determining all interactions through learning algorithms. This will allow us to solve previous limitations of regression models, providing a higher level of explained variance, which will result in a better understanding and quantification of how various drivers affect the development of innovation (Minbashian et al., 2010; Somers & Casal, 2009). On the other hand, cluster analysis empowers us to uncover patterns and segment data into homogeneous sets, thereby enriching our understanding of the studied population and facilitating the identification of relevant subgroups.

Our research plan reveals several stages. First, we investigate the integration dynamics of these strategic orientations within SMEs, exploring how different levels of integration impact their innovation strategies. Our methodological approach is grounded in a robust analysis of the EU database, combining regression, machine learning and cluster tools to uncover patterns and relationships. By adopting a dynamic perspective, we aim to investigate the complexities of digital and CE integration, offering insights into the mechanisms that drive innovation within SMEs.

The results aim to clarify the paths through which SMEs develop the integration of digital transformation and CE, providing a comprehensive understanding of the factors that facilitate or hinder innovation in this context. These insights will not only enrich academic discourse but also hold practical implications for businesses and policymakers. By providing strategies for overcoming challenges, our study contributes to explaining the way for SMEs to effectively harness the benefits of digitalisation and sustainability, thus fostering innovation, economic growth and environmental conservation. In essence, this research endeavours to offer a roadmap, guiding SMEs towards innovative practices that are not only technologically advanced but also environmentally sustainable, thereby contributing significantly to the broader landscape of corporate innovation and societal progress.

2 | THEORETICAL BACKGROUND

2.1 | The circular economy in the firm

The circular economy is conceptualized as an economic model of production and consumption in a closed cycle, where waste serves as an input for the production cycle (Ferasso et al., 2020; Fernandez de Arroyabe et al., 2021; Frishammar & Parida, 2019; Rosa et al., 2019). Unlike the classic line economic model, where products are discarded at the end of their life, the circular economy model is based on the *reuse, remanufacturing and recycling* of the product, which implies changing the concept of end-of-life production and consumption for re-using (Hopkinson et al., 2018; Linder & Williander, 2017; Pieroni et al., 2019). Thus, from the environmental point of view, the CE model proposes a more efficient use of resources and the total reduction of resource inputs, energy, emissions and the resulting waste leakage, reducing negative environmental impacts without endangering growth and prosperity, combined with a sustainable economy (Linder & Williander, 2017; Rosa et al., 2019).

The CE model proposes continuous cycle industrial systems, where the product in its final phase is used again as an input in the productive system. This has important implications for the productive system, from the promotion of durable design, proactive maintenance, recycling, repair, renewal and remanufacturing (Ferasso et al., 2020; Fernandez de Arroyabe et al., 2021). Thus, the CE model is an economic system of recycling and reuse of resources where the reduction of elements is imperative, that is, reduce production to a minimum and opt for the reuse of elements that due to their properties cannot be returned to the environment.

The implementation of circular economy principles presents significant barriers and challenges for SMEs. Ardito et al. (2021) point out that a primary challenge stems from the financial constraints and lack of specialized knowledge inherent in many SMEs, hindering their ability to invest in sustainable technologies and processes. The adoption of circular economy practices often entails substantial initial costs and demands considerable resources, posing a formidable challenge for smaller enterprises operating within tight resources. Moreover, essential to a circular economy is the design of products that can be easily disassembled, repaired and recycled, a task requiring expertise in eco-design and product lifecycle analysis. SMEs frequently lack this expertise and competencies, making it challenging to create products with circularity at their core (Madrid-Guijarro & Duréndez, 2024; Zhang & Walton, 2017). Additionally, many SMEs adhere to traditional linear business models (make, use, dispose), making the transition to circular business models, like product-as-a-service or leasing arrangements, a difficult undertaking. Such a shift necessitates a fundamental change in mindset and operational strategies, a transformation that proves arduous for many SMEs (Guandalini, 2022).

2.2 | Digital transformation

Digital transformation in companies involves the implementation of digital technologies to *disruptively transform production systems, work organization and strategic decision-making* (Díaz-Chao et al., 2021, p.2). In fact, digital technologies combined with production management systems are the factor for digital transformation (Bai et al., 2020; Fliaster & Kolloch, 2017), allowing to increase efficiency and quality in manufacturing and supply chains by automating different aspects of production (Brenner & Hartl, 2021; Dabrowska et al., 2022).

Digital transformation of companies is carried out through the incorporation of digital technologies such as big data, cloud computing, artificial intelligence and machine learning (AI/ML), smart devices, robotics, data analytics and blockchain, among others, which implies the integration of intelligent machines, storage systems and smart production systems, through the use of wireless sensor networks, communication protocols, distributed control systems and cloud computing.

The digital transformation within SMEs presents significant challenges and barriers, primarily due to the unique characteristics of these businesses (Guandalini, 2022; Somohano-Rodríguez et al., 2022; Masood & Sonntag, 2020; Moeuf et al., 2019). One major obstacle lies in the limited financial and human resources inherent to SMEs, constraining their ability to invest in new digital technologies (Ardito et al., 2021). Additionally, as noted by Masood and Sonntag (2020), a second barrier arises from the lack of in-house expertise related to digital technologies. Many SMEs lack professionals proficient in digital systems, data analytics, cybersecurity and other essential aspects of digital transformation. Moreover, integrating these new technologies with existing systems proves to be a complex and costly task (Masood & Sonntag, 2020; Moeuf et al., 2019). Resistance from both employees and management constitutes a significant hurdle (Ardito et al., 2021; Ocasio, 2010). This resistance can be attributed to a lack of understanding, concerns about potential job displacement or a general reluctance to depart from established familiar processes.

2.3 | Strategic orientation

Narver and Slater (1990) consider that a firm's strategic orientation reflects the strategic directions implemented by a firm to create the proper behaviours for the continuous superior performance of the business. From a strategic point of view, a firm's strategic decisions suppose that companies emphasize developing resources and capabilities in tandem with their strategic orientations (Ferrell et al., 2010; Mallin et al., 2013; Zhou et al.,). The strategic orientations seek to create environments at the company level where the desired behaviours and actions are supported and implemented, which implies that the strategic orientation uses the resources and capabilities of the company (Gatignon & Xuereb, 1997; Ardito et al., 2021).

Traditionally, scholars have explored three dimensions of strategic orientation: market, technological or entrepreneurial orientation (Gatignon & Xuereb, 1997; Narver & Slater, 1990; Zhou et al.,). More recently, additional dimensions have been conceptualized as 'digital orientation' and 'environmental orientation'. First, digital orientation reflects the strategic decision to digitalize a firm's organisational functions (Ardito et al., 2021), introducing digital technologies in an interconnected environment through the internet of things (IoT) (Masood & Sonntag, 2020). Environmental orientation reflects the strategic decision to integrate environmental priorities into the activities of the companies (Ardito et al., 2021; Linder et al., 2014; Niemann et al., 2020). In this line, the implementation of the CE model requires new visions and strategies and a fundamental redesign of product concepts, service offerings and channels towards long-life solutions (Frishammar & Parida, 2019; Hopkinson et al., 2018).

Strategic orientation within SMEs denotes the intricate process of aligning organisational strategies with its objectives and market realities, aiming to attain a sustainable competitive edge. In navigating this terrain, SMEs encounter distinctive challenges. Notably, these businesses frequently deal with limited financial and human resources, impeding their ability to invest in vital strategic planning processes, comprehensive market research and the implementation of enduring strategies (Aragón-Sánchez & Sánchez-Marín, 2005). Moreover, Salavou et al. (2004) pointed out that SMEs often find themselves operating within fiercely competitive and swiftly evolving markets, demanding constant vigilance to stay abreast of market trends and shifting customer preferences and technological innovations. Successfully adapting strategies to these dynamic landscapes necessitates a rare blend of flexibility and agility. In the context of SMEs, particularly those rooted in family ownership, a pronounced inclination toward risk aversion can prevail (Brustbauer, 2016; Kumar et al., 2012). This risk aversion can deter these enterprises from undertaking bold strategic initiatives, driven by the apprehension of failure. Consequently, this cautious approach can stifle innovation and limit exploration into new market opportunities. Furthermore, many SMEs are characterized by concentrated leadership, typically vested in a handful of individuals, often the owners or founders. If these leaders lack a strategic vision or exhibit resistance to change, the coherent development and effective implementation of strategic orientation can be significantly hampered, posing an additional challenge to these enterprises.

3 | HYPOTHESES

As we have previously pointed out, our paper addresses how SMEs integrate digital orientation and CE. At this point, we argue that both digitalisation and CE are considered strategic orientations that SMEs can implement. For SMEs, this means establishing an attitude that commits the organisation to the implementation of digital technologies and CE practices, allocating resources and creating competencies and skills towards the implementation of these strategic guidelines.

3.1 | Integration of digital and CE strategic orientations in the SMEs

Previous literature about the integration of digitalisation and CE highlights the challenge of balancing both orientations, as they compete for resources and management within the company, generating difficult situations in the company. In particular, Moeuf et al. (2019) and Ardito et al. (2021) suggest the incompatibility of these two orientations, based on the fact that the knowledge, relational and human resources necessary to implement the digital and environmental orientations are different and address different objectives, being especially critical for SMEs as consequence of their limited level of resources. More in particular, with a limited number of employees, SMEs face challenges in managing the diverse tasks and skills required by digital and environmental orientations. This can be overwhelming for employees, who may struggle to absorb and assimilate the added workload and dedicate the necessary time and effort to these various activities, which may be spread across different projects (Ardito et al., 2021; Ocasio, 2010).

Despite this situation, our position suggests that both strategic orientations can coexist and even be compatible. First, Bag et al. (2020) and Santoalha et al. (2021) point out that digital technologies facilitate environmental outcomes by helping companies build sustainability-oriented capabilities to adopt circular manufacturing techniques and minimize waste. For example, Rodríguez-González et al. (2023) indicate that the implementation of digital technologies supports sustainability through business digitisation and the enhancement of the value of digital technologies, resulting in waste reduction, creation of new products and services, optimisation of business operations and attention to supply chain practices. Second, Siguaw et al. (2006) and Adams et al. (2016) emphasize that the implementation of various orientations is a dynamic process, characterized by various levels of integration, (i) from proactivity, where companies take the initiative and address the objectives and actions to implement these strategic orientations, (ii) to reactivity, where due to market, stakeholder or regulatory pressures, companies implement strategies without a high level of commitment. This is consistent with the literature that highlights that SMEs have a distinctive feature, along with their flexibility, of being reactive in implementing their strategic orientations (Ardito et al., 2021), which allows for different levels of integration of the various strategic orientations. In particular, Guandalini (2022) argues that both orientations can coexist under the institutional pressures to adopt sustainable business practices. In this sense, SMEs can adopt CE practices together with digitalisation, especially in manufacturing sectors, where digitalisation is not only key to the competitiveness of firms but is an imperative of the supply chain of the company, in order to comply with normative and regulatory requirements, such as achieving the zero waste certification (Spanish Standardization Association, AENOR) or following the eco-design requirements set by the Directive 2009/125/EC (Fernandez de Arroyabe et al., 2021). Therefore, given these arguments, regarding the integration of the digital and CE orientations in SMEs, we propose that the two orientations can coexist, with companies prioritising one strategic orientation over the other resulting in a diversity of SMEs' digital and CE-related behaviours.

One the one hand, some firms emphasize digital transformation more than CE practices. For SMEs, digital transformation offers significant advantages, enhancing operational efficiency, decision-making processes, customer experiences and overall competitiveness in today's market. Consequently, it can lead to reduced energy and waste costs in the production process through the incorporation of CE guidelines. This integration can be exemplified by certifications like XP X30-901 (French Standardization Association, AFNOR), which promotes best practices for achieving the CE model (AFNOR, 2018), or BS 8001 (British Standard), providing an organisational framework for CE implementation (BSI, 2017). In this category of companies, the adoption of CE practices can be viewed as an externality resulting from digital orientation (Arranz et al., 2022; Fernandez de Arroyabe et al., 2021). This often translates into a reactive environmental orientation, limited to compliance with existing regulations. Due to the constraints of limited resources and capabilities inherent in SMEs, this group prioritizes digitalisation over CE orientation.

Moreover, considering the extent of digitalisation, it becomes apparent that high levels of digitalisation yield synergistic effects. These effects, driven by knowledge management systems and their impact on organisational structures, facilitate the integration of CE orientations (Fagerberg, 2018). High digitalisation levels act as facilitators for CE integration due to the complementary nature of these processes. Scholars already acknowledge that digitalisation creates a network of relationships within the supply chain. Masood and Sonntag (2020) underscore the connectivity aspect intrinsic to the digitalisation process, emphasising Industry 4.0 and the IoT, both of which facilitate the adoption of sustainable models like CE (Awan et al., 2021). Furthermore, high digitalisation levels often involve the use of cloud computing alongside AI or ML techniques and big data analytics. This amalgamation positively impacts market prospects, easing the introduction of eco-innovations and, subsequently, advancing CE implementations. Hence, we propose our initial hypothesis, positing that high levels of digitalisation serve as facilitators for the integration of CE orientations.

Hypothesis 1a. Extensive level of digitalisation within SMEs will enhance the integration of CE orientation.

On the other hand, a distinct group of companies can be identified, demonstrating a strong commitment to CEprinciples, albeit integrating digital technologies to a lesser extent, such as cloud computing for safeguarding data against potential cyber threats (Bai et al., 2020; Masood & Sonntag, 2020). The efficiency gains linked with digital technologies imply that digital transformation can encourage industrial sustainability by curbing waste and energy consumption; enhancing data flows; enabling product tracking, managing waste, by-products and carbon footprints in the supply chain; and facilitating the intelligent disassembly of components for reuse and recycling (Bai et al., 2020; Brozzi et al., 2020; Díaz-Chao et al., 2021). Moreover, real-time data streams resulting from machine-to-machine communication and electronic product tagging could streamline the implementation of the circular economy model, fostering vertically integrated and cross-industry networks with closed material loops. Scholars have emphasized the pivotal role of digital technologies in facilitating the development of CE models, enabling enhanced communication among partners.

However, when transitioning to advanced stages of CE integration, and considering the limited human and managerial resources, the reciprocal synergistic effects between digitalisation and CE, observed at earlier stages, do not manifest in the same manner. Existing literature, from the perspective of dynamic capability, underscores that the innovation process in organisations necessitates the mobilisation of resources, capabilities and organisational routines (Arranz et al., 2019). It emphasizes the synergies that emerge when companies engage in diverse forms of innovation within their organisations (Arranz et al., 2019). In the context of high levels of CE integration, extensive digitalisation does not occur, as high levels of CE do not contribute to creating competencies in analytical tools or big data, for example. Instead, it involves the introduction of specific digital technologies such as smart devices and cloud computing, streamlining information processes and material flow. Hence, we propose the following hypothesis:

Hypothesis 1b. SMEs implementing advanced CE orientation do not necessarily exhibit a corresponding high level of digitalisation.

3.2 | Integration of digital and CE strategic orientations and the effect on the innovation of SMEs

The second point that we analyse in our research is how the integration of digital and CE strategic orientations affects the innovation of SMEs. In this sense, we can point out that adopting the strategies separately is found in the literature to have a positive effect on the innovative development of the company. That is, the implementation of digital technologies can improve innovation in SMEs (Ardito et al., 2021; Bharadwaj et al., 2013), increasing the levels of productivity, efficiency and financial and human resources cost savings (Ghobakhloo, 2020; Horvath and Szabo, 2019). Additionally, digitalisation can be used to manage the flow of information and access customer data, processes and products throughout the supply chain, which have a significant impact on the innovation performance of companies (Ardito et al., 2021; Moeuf et al., 2019; Rummel et al., 2022). On the other hand, orientations towards CE allow companies to develop new products and services (Seebode et al., 2012; Jin et al., 2019; Ghobakhloo, 2020; Arranz et al., 2022). Following Somohano-Rodríguez et al. (2022), another significant factor that promotes green operational practices in SMEs is customer pressure. Nowadays, SME customers demand products and services that respect the environment. Moreover, companies can align innovation by taking into account environmental regulations or being geared towards the needs of both customers and suppliers who demand environmentally compatible products (Brenner & Hartl, 2021; Cillo et al., 2019; Fliaster & Kolloch, 2017; Rodríguez-González et al., 2022).

Therefore, regarding the integration of both orientations and their effect on the innovations of SMEs, we can point out, in line with the actions of both strategic orientations separately, that these two orientations can not only be compatible but also have synergistic effects, which can be a facilitator of the probability of innovation of SMEs. According to Ardito et al. (2021), sustainable and digital innovations have different characteristics, with sustainable innovations having a high exploratory component and digital innovations having an exploitative component. In this sense, Rothaermel and Deeps (2004) emphasize that the innovation process is a sequential one where both exploration and exploitation capacities are integrated until the achievement of innovation. Therefore, this difference in the innovative capacities of both strategies can reinforce innovation in SMEs.

Thus, based on previous arguments, we consider that greater integration of both CE and digital strategic orientation will have a positive effect on the innovative development of SMEs. Hence, we propose

> **Hypothesis 2.** A greater integration of both CE and digital strategic orientations will have a greater positive effect on the innovative development of SMEs than a lesser integration of both strategic orientations.

4 | METHODOLOGY

To empirically test the hypotheses, we use the database from the Eurostat Flash Eurobarometer No. 486, which is conducted for the European Commission (Eurostat, 2022). The FL486 survey on "SMEs, start-ups, scale-ups and entrepreneurship" was conducted in the EU27 and an additional 12 non-EU countries and territories, and focuses on the barriers and challenges that SMEs in Europe face when growing, transitioning to more sustainable business models and digitalisation. The survey collected responses from more than 16,000 telephone interviews with enterprises employing one or more persons between 19 February and 5 May 2020. Interviews were conducted by phone in their respective national language, providing a final sample of 16,365 SMEs.

Regarding the distribution based on size, 62% of the companies are microenterprises (one to nine employees), 22.5% are small companies (ten to 49 employees) and 15.5% are medium-sized companies (50 to 249 employees). Regarding the age of the sample, as shown in Table 1, we observe that the majority of the companies are highly established, with about half of the companies formed before 2000, and only 10% of the firms established after 2015. Moreover, the companies are distributed across 16 business sectors, corresponding to manufacturing at 19.5%, retail at 27.7% and scientific and technical activities at 9.3%. Table 2 shows the geographical distribution of the SMEs, with a good balance of companies across countries (see Table 2).

TABLE 1 Age of SME's sample.

Age of SME	Frequency	Per cent
2019 and after	169	1.0
Between 2015 and 2018	1,499	9.2
Between 2000 and 2014	6575	40.2
Before 2000	7732	47.2
Missing	390	2.4
Total	16,365	100.0

4.1 | Measures

The first group of measures refers to the strategic orientation of the firm. In line with previous works, we assume that strategic orientation can have different degrees of implementation, and these are measured by the actions implemented by the SMEs (Mallin et al., 2013; Zhou et al.,). The first variable is digitalisation, which is measured by the degree of implementation of digital technologies. The questionnaire asks the following question: Which of the following digital technologies, if any, has your enterprise adopted to date? (i) AI, for example, ML or technologies identifying objects or persons; (ii) cloud computing, that is, storing and processing files or data on remote servers hosted on the internet; (iii) robotics, that is, robots used to automate processes, for example, in construction or design; (iv) smart devices, for example, smart sensors and smart thermostats; (v) big data analytics, for example, data mining and predictive analysis; (vi) high-speed infrastructure; and (vii) blockchain. Following Arranz et al. (2019), the variable *digitalisation* was formed as a cumulative index of the seven types of digital technologies (AI, cloud computing, robotics, smart devices, big data analytics, high-speed infrastructure, blockchain), measuring the level of digitalisation of SMEs.

The second measure is the strategic orientation towards CE. As in the previous measure, we use a multi-item question. The question included in the questionnaire related to CE is about slowing, closing or narrowing resource flows (i.e. energy or materials) (Pieroni et al., 2021). The question asks which of the following actions, if any, is your enterprise actively taking? (i) recycling or reusing materials; (ii) reducing consumption of or impact on natural resources (e.g. saving water or switching to sustainable resources); (iii) saving energy or switching to sustainable energy sources; and (iv) developing sustainable products or services. Thus, as with the previous variable, the *CE* variable is created as a cumulative index.

The third variable is innovation, considering five types of innovation in companies (Arranz et al., 2019; Oke, 2007). The multi-item question posed is the following: Has your enterprise introduced any of the following types of innovations? (i) a new or significantly improved product or service to the market, (ii) a new or significantly improved production process or method, (iii) a new organisation of management or a new business model and (iv) a new way of selling your goods or services. In line with previous variables, *innovation* is created as a cumulative index.

TABLE 2 The sector of SME's sample.

Sector	Frequency	Percent
B—Mining and quarrying	90	.5
C—Manufacturing	3184	19.5
D—Electricity, gas, steam and air conditioning supply	100	.6
E—Water supply, sewerage, waste management/remediation activity	167	1.0
F—Construction	1576	9.6
G—Wholesale and retail trade, repair of motor vehicles and	4532	27.7
H—Transportation and storage	929	5.7
I—Accommodation and food service activities	919	5.6
J—Information and communication	625	3.8
K—Financial and insurance activities	344	2.1
L—Real estate activities	376	2.3
M—Professional, scientific and technical activities	1524	9.3
N—Administrative and support service activities	720	4.4
P—Education	383	2.3
Q—Human health and social work activities	622	3.8
Arts, entertainment and recreation	274	1.7
Total	16,365	100.0

4.2 | Variables of control

To control for the impact of external factors on the results, we include a set of control variables that refer to the ecosystem where the company is located. In this sense, there is a wealth of literature showing that a favourable ecosystem, in terms of financial support, knowledge or regulations, has a positive impact on the digitalisation, CE and innovation of companies (see, for example, Sussan & Acs, 2017; Helfat & Raubitschek, 2018). The control variables are measured using the following question: How would you rate your business environment in terms of (i) overall strength and performance of your regional business environment; (ii) access to and collaboration with business partners, including other enterprises, the public sector, educational institutions and research organisations; (iii) availability of staff with the right skills, including managerial skills; and (iv) infrastructure for business. We use a Likert scale from 0 to 5.

The second group of control variables pertains to internal aspects of SMEs, such as the *size* and the company's age (*year*). Regarding size, we categorized the companies into three groups: from 0 to 9 employees as microenterprises, from 10 to 49 employees as small enterprises and from 50 to 250 employees as medium-sized enterprises. The second control variable is the year of establishment. In this context, the variable of age has served as a moderating factor in digitalisation and sustainability in a wide array of studies (see, for example, Lythreatis et al., 2022).

5 | ANALYSIS OF RESULTS

Before analysing the results, we performed checks of the survey to verify the robustness of the questionnaires and answers, testing the common method variance (CMV) and common method bias (CMB), following the method of Podsakoff et al. (2003). This analysis reveals five distinct latent constructs that account for 61.01% of the variance. The first factor accounts for 24.927% of the variance, which is below the recommended limit of 50%. This result suggests that CMV and CMB are not a concern in our results.

In Table 3, we show the results of the descriptive analysis of both the digitalisation and CE variables. Regarding digitalisation, we see that the most adopted technologies are related to IT services and information security, such as cloud computing (47.9%) and high-speed infrastructure (33.7%). At a lower level of integration, we find both technologies applied to process automation such as smart devices (27.8%), as well as prediction and analysis techniques (big data analytics, 14.5%). Lastly, with a low level of adoption, AI techniques (7.7%) and blockchain (3.3%). Regarding the results of the strategic orientations taken by the SMEs in terms of the implementation of CE models, we observe that the most integrated strategies have to do with recycling or reusing materials (59%) or reducing consumption of or impact on natural resources (e.g. saving water or switching to sustainable resources) (49.6%). It is also common for companies to take energy-saving measures (saving energy or switching to sustainable energy sources, 50.5%), with the consequent implications in terms of costs. Lastly, and with a lower level of integration, firms develop actions of developing sustainable products or services (32.0%).

Before hypothesis testing, we conducted a regression analysis to examine the impact of the independent and control variables on innovation. The results are presented in Table 4. In Model 4, our findings reveal a positive and significant coefficient for the cumulative index measuring the level of digitalisation ($\beta = 0.165$; $p < .001$) as well as for CE orientation ($\beta = 0.1489$; $p < .001$), indicating a positive effect. Furthermore, we explored the combined effect of both variables on innovation, identifying a positive impact ($\beta = 0.008$; $p < .005$). As for the control variables, we observe that both the environment and the size have a positive effect on digitisation (Table 5).

TABLE 3 Descriptive analysis of digitalisation and sustainability variables.

Digitalisation	Companies	
1. Artificial intelligence, e.g., machine learning or technologies identifying objects or persons	1252	7.7%
2. Cloud computing, i.e., storing and processing files or data on remote servers hosted on the internet	7836	47.9%
3. Robotics, i.e., robots used to automate processes for example in construction or design	1403	8.6%
4. Smart devices, e.g., smart sensors, smart thermostats, etc.	4549	27.8%
5. Big data analytics, e.g., data mining and predictive analysis	2368	14.5%
6. High-speed infrastructure	5521	33.7%
7. Blockchain	541	3.3%
CE		
1. Recycling or reusing materials	9784	59.8%
2. Reducing consumption of or impact on natural resources (e.g. saving water or switching to sustainable resources)	8110	49.6%
3. Saving energy or switching to sustainable energy sources	8269	50.5%
4. Developing sustainable products or services	5239	32.0%
Total	**16,365**	**100.0%**

We have now added a table in the empirical analysis as a robustness check, where we address the potential endogeneity of digitalisation by employing the control function approach (CFA). In the first stage (columns 1–3 in Table 6), we have regressed the potentially endogenous variable (digitalisation) on the selected instrument (manager's perception regarding the necessity of digital technology adoption) and the other exogenous variables. In the second stage, we have included the residuals from this first-stage regression as an additional explanatory variable in the main regression model where innovation serves as the dependent variable. We assessed the strength of our instrument by looking at the *F*-statistic from the first-stage regression. The results (see the last row in Table 6) indicate a sufficiently large *F*-statistic, suggesting that the instruments are strong and relevant, thereby reducing concerns related to weak instrument bias. Specifically, an *F*-statistic is well above the critical value of 10 in all three specifications (see columns 1–3).

Concerning the theoretical validity of our instrument, our choice is based on the hypothesis that managers' perceptions significantly influence organisational decisions and behaviours, specifically the adoption of new technologies. Theoretical frameworks in technology adoption, such as the Technology Acceptance Model (TAM) and the Theory of Planned Behaviour (TPB), suggest that subjective norms and perceived usefulness strongly affect the intention to use and the actual use of new technologies. In the context of our study, if a manager perceives no need for digital technologies, the firm will likely adopt fewer technologies or delay adoption, directly impacting the number of technologies adopted. This behaviour aligns with the managerial prerogative theory, which asserts that managers' strategic choices in technology adoption can shape firm capabilities and performance pathways. The exogeneity of this instrument hinges on the assumption that the manager's perception impacts innovation only through its effect on the adoption of digital technologies. This

TABLE 4 Regression analysis and innovation.

	(1)	(2)	(3)	(4)	(5)
SIZE	0.000**(0.000)	− 0.000(0.000)	0.000(0.000)	− 0.000(0.000)	− 0.000(0.000)
REGIONAL SUPPORT	0.308***(0.037)	0.180***(0.035)	0.168***(0.035)	0.112***(0.034)	0.112***(0.034)
COLLABORATION	0.256***(0.036)	0.158***(0.034)	0.179***(0.034)	0.127***(0.033)	0.126***(0.033)
SKILLS	0.055(0.037)	0.066*(0.035)	0.110***(0.035)	0.102***(0.034)	0.100***(0.034)
INFRASTRUCTURE	0.133***(0.033)	0.005(0.031)	0.120***(0.031)	0.026(0.030)	0.026(0.030)
AGE	0.000**(0.000)	0.000*(0.000)	0.000*(0.000)	0.000*(0.000)	0.000*(0.000)
DIGITALISATION		0.242***(0.006)		0.185***(0.006)	0.165***(0.011)
CE			0.225***(0.006)	0.159***(0.006)	0.148***(0.008)
DIGIT&CE					0.008**(0.004)
Constant	0.397***(0.113)	0.243**(0.107)	0.061(0.108)	0.042(0.105)	0.062(0.105)
Observations	16,365	16,365	16,365	16,365	16,365
R-sq.	0.035	0.135	0.122	0.173	0.173
Log. likelihood	− 23,806.759	− 22,908.215	− 23,026.529	− 22,537.678	− 22,535.404
Industry dummies	Yes	Yes	Yes	Yes	Yes

Standard errors in parentheses. *$p < 0.1$, **$p < 0.05$, ***$p < 0.01$.

TABLE 5 Summary statistics.

Variable	Mean	SD	p25	p50	p75
INNOVATION	0.849	1.056	0.000	1.000	1.000
DIGITALISATION	1.434	1.432	0.000	1.000	2.000
CE	1.919	1.409	1.000	2.000	3.000
SIZE	59.298	709.756	3.000	7.000	24.000
REGIONAL SUPPORT	0.558	0.239	0.500	0.500	0.500
COLLABORATION	0.527	0.244	0.333	0.500	0.500
SKILLS	0.501	0.238	0.333	0.500	0.500
INFRASTRUCTURE	0.640	0.269	0.500	0.500	1.000
AGE	24.676	21.427	11.000	20.000	30.000

TABLE 6 Robustness check of regression analysis.

	(1)	(2)	(3)	(4)	(5)	(6)
	Digitalisation	Digitalisation	Digitalisation	Innovation	Innovation	Innovation
DIGITALISATION				0.508***(0.041)	0.486***(0.047)	0.462***(0.046)
CE		0.349***(0.007)	0.366***(0.008)		0.052***(0.018)	0.043**(0.017)
DIGIT&CE						0.008**(0.004)
SIZE	0.000***(0.000)	0.000***(0.000)	0.000***(0.000)	− 0.000***(0.000)	− 0.000***(0.000)	− 0.000***(0.000)
REGIONAL SUPPORT	0.527***(0.048)	0.310***(0.045)	0.311***(0.045)	0.041(0.041)	0.021(0.037)	0.022(0.037)
COLLABORATION	0.384***(0.047)	0.269***(0.044)	0.272***(0.044)	0.050(0.038)	0.042(0.036)	0.042(0.036)
SKILLS	− 0.031(0.049)	0.052(0.046)	0.058(0.046)	0.078**(0.035)	0.090***(0.034)	0.088**(0.034)
INFRASTRUCTURE	0.518***(0.043)	0.499***(0.040)	0.499***(0.040)	− 0.136***(0.038)	− 0.127***(0.038)	− 0.124***(0.038)
AGE	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)	0.000(0.000)
INSTRUMENT	− 0.508***(0.029)	− 0.431***(0.027)	− 0.256***(0.043)			
INSTRUMENT& CE			− 0.099***(0.019)			
Residuals				− 0.271***(0.041)	− 0.305***(0.047)	− 0.301***(0.045)
Constant	0.779***(0.149)	0.237*(0.140)	0.193(0.140)	0.074(0.110)	0.011(0.105)	0.030(0.105)
Observations	16,365	16,365	16,365	16,365	16,365	16,365
R-sq.	0.089	0.204	0.205	0.137	0.175	0.176
Log. likelihood	− 28,322.797	− 27,224.183	− 27,210.598	− 22,886.252	− 22,516.693	− 22,512.863
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes
F-statistic instrument	313.71	257.05	35.69	-	-	-

assumption is plausible if we consider that perceptions are shaped by individual experiences, biases and information asymmetry rather than by the firm's current innovation activities or performance. Managers' views about technology needs are likely formed based on their exposure to industry trends, competitive pressures and personal efficacy in technology management, rather than the direct outcomes of innovation processes within the firm. Thus, while these perceptions influence the decision-making process regarding digital technology adoption, they are exogenous to the specific innovations being developed or implemented by the firm at any given time. The theoretical validity of this instrument is further supported by empirical evidence from prior studies indicating that managerial attitudes towards technologies can precede and dictate organisational technology strategies rather than result from them (e.g. Davis, 1989; Leonard-Barton & Deschamps, 1988).

Moreover, to comprehensively understand the impact of independent and control variables on the innovative development of SMEs, we extend our previous regression analysis by incorporating artificial neural networks (ANN). The integration of ANN in our study enables us to explore the intricate relationships among input variables, such as digitalisation and CE orientation, and their influence on the output variable. For the simulation with ANN, we use the typology of ANN as a multilayer perceptron (MLP). In the context of neural networks, the architecture is referred to as that of a supervised network, which is so named because the predicted results can be compared with known values of the output variables. Specifically, the architecture of a MLP consists of an input layer, one or more hidden layers and an output layer. By connecting the neurons in the hidden and output layers with their respective weights, it becomes possible to analyse the interaction between the input variables. This approach is crucial as it allows us to account for nonlinearities and the multitude of interactions that exist within the context of SME innovation. To design the ANN-MLP architecture, we follow Wang (2007).[1] Figure 1 shows the ANN-MLP architecture for the simulation, structuring in 8 input nodes, 5 nodes in the hidden layer and 1 node of the output variable. Figure 2 illustrates the normalized importance of each input variable concerning the output variable.[2] We observe that digitalisation has the highest effect on innovation (digitalisation 0.379; 100% normalized value), following the CE orientation (CE 0.327; 86.4% normalized value); however, the control variables have a very low impact on the innovative development of SMEs, especially when compared with digitisation and CE. Additionally, we assessed the robustness of the analysis, getting a fitting of the ANN-MLP design, which demonstrated a fitting level exceeding 70%.

Regarding Hypotheses 1a and 1b, as SMEs integrate both digitalisation and CE, we have carried out a cluster analysis, with the aim of classifying SMEs according to their level of integration of digitalisation and CE orientations. The objective of the cluster analysis is to investigate the existence of different behaviours and groups of companies depending on their level of integration of the digitalisation and CE orientations, using the K-mean cluster as a statistical model. Following Dudek (2020) and Mamat et al. (2018), we have proceeded in three stages. First, the input variables for the K-means cluster analysis are digitalisation and CE orientation strategies. Second, the K-means analysis is conducted by considering solutions from 2 clusters to 10 clusters. Solutions greater than 10 clusters are hardly feasible considering that the input variables are two so the solution from 2 to 10 clusters includes all the possible combinations of the input variables. Third, we proceed to the choice of the most robust solution. For this, we use Silhouette analysis (Dudek, 2020; Mamat et al., 2018; Fraley & Raftery, 1998). This analysis allows us to determine the robustness of the cluster solution, the cohesion of each cluster and the separation of the groups. Silhouette index[3] takes values in the interval [− 1, 1], with values closer to 1 being the most robust solution. After proceeding to obtain the Silhouette index, the four-cluster solution has a higher value (0.69). Furthermore, we performed a complementary analysis, using the Schwarz' Bayesian criterion (Fraley & Raftery, 1998; Kass & Wasserman, 1995), and the results confirm that the solution four clusters are the most robust in terms of cohesion and separation.

Table 7 shows the results obtained, with a distribution of the companies in four clusters. Previously, we checked the robustness of the four-cluster solution by performing an ANOVA analysis (Table 8). That is, using cluster membership as a control variable and digitalisation and CE as variables, the results show significant differences between each cluster in terms of digitalisation (*F* 10,598.569; significance 0.000) and CE (*F* 15,477.625; significance 0.000), as shown by the significance of the *F* test. Additionally, we have conducted another test of the robustness of the cluster analysis, checking the nonexistence of bias derived from the measurements created. In this case, we have performed the cluster analysis with the CE and digitalisation variables obtained with factor analysis, to compare the solution with a variable such as cumulative index. With our results, we can confirm that there is no bias, both in the distribution of the companies and their profile, obtaining levels of membership of the companies in each cluster above 80% (cluster 1 84.7%; cluster 2 85.9%; cluster 3 93.4%; cluster 4 100%).

Table 7 displays the profiles of each cluster, showing the mean values of the CE and digitalisation variables in them. Figure 3 illustrates the distribution of SMEs with a scatter plot, utilising digitalisation and CE as variables. The horizontal axis represents the cluster membership of each SME, while the vertical axis shows the mean values of digitalisation and CE. The results show that 43.2% of the SMEs (Cluster 2) have very low levels of integration of digitalisation and CE, with the average values of adoption being less than 1 in both variables. Cluster 1, formed by 34.9% (7,719 SMEs), shows a higher level of CE (mean > 3.0) than digitalisation, with an average value close to 1. Moreover, Cluster 3, made up of 1653 SMEs (10.1%), shows an inverse profile to Cluster 1, prioritising digitalisation over CE. Finally, Cluster 4 (1923; 11.8%) combines the two strategic lines of CE and digitalisation, with a high average level (mean < 3 in both orientations). Moreover, Table 9 presents the profiles of each cluster, based on the size of the SME, sector of belonging, digital technologies

[1]In the procedure of design of the ANN-MLP architecture, we can distinguish two key points: (i) the choice of the number and size of the hidden layers and (ii) the choice of the learning algorithm. First, while the number of inputs and outputs of the proposed network is given by the number of available input and output variables, the number and size of hidden layers are determined by testing several combinations of the number of hidden layers and the number of neurons, using a trial and error approach (Ciurana et al., 2008; Mohrotra, 1994). That is, the selected architectures are tested with diverse activation functions, finding that the best architecture is one that minimizes the error. The analytical equation of our simulation with ANN-MLP takes the following form for the case of the level of digitalization:

$$Innovation = h\left[\sum_{k=1}^{6} \alpha_k \cdot g\left(\sum_{j=1}^{6} \beta_{jk} \cdot X_j\right)\right]$$

with X_j being the input variable;
j the number of input variables;
$h(.)$ and $g(.)$ the hyperbolic tangent and softmax activation functions;
α_k and $ß_{jk}$ the input and hidden network weights, respectively;
k the number of hidden layers.

[2]Ibrahim (2013) revises some methods for assessing the relative importance of input variables in artificial neural networks. These methods are based on Garson's algorithm, which uses the absolute values of the final connection weights when calculating variable contributions. $RI_x = \sum^{n} \frac{|w_{xy}\, w_{yz}|}{\sum_{y=1}^{m} |w_{xy}\, w_{yz}|}$ where RI_x is the relative importance of neuron x. $\sum_{y=1}^{m} w_{xy}\, w_{yz}$ represents the sum of the product of the final weights connection from input neurons to hidden neurons with the connnections from hidden neurons to output neurons.

[3]The Silhouette coefficient (s) is calculated using the mean intracluster distance (a) and the mean nearest-cluster distance (b) for each sample. The algorithm is for every $cluster_i$:

$$\mathbf{s(i)} = \frac{\mathbf{b(i) - a(i)}}{\mathbf{max(b(i), a(i))}}$$

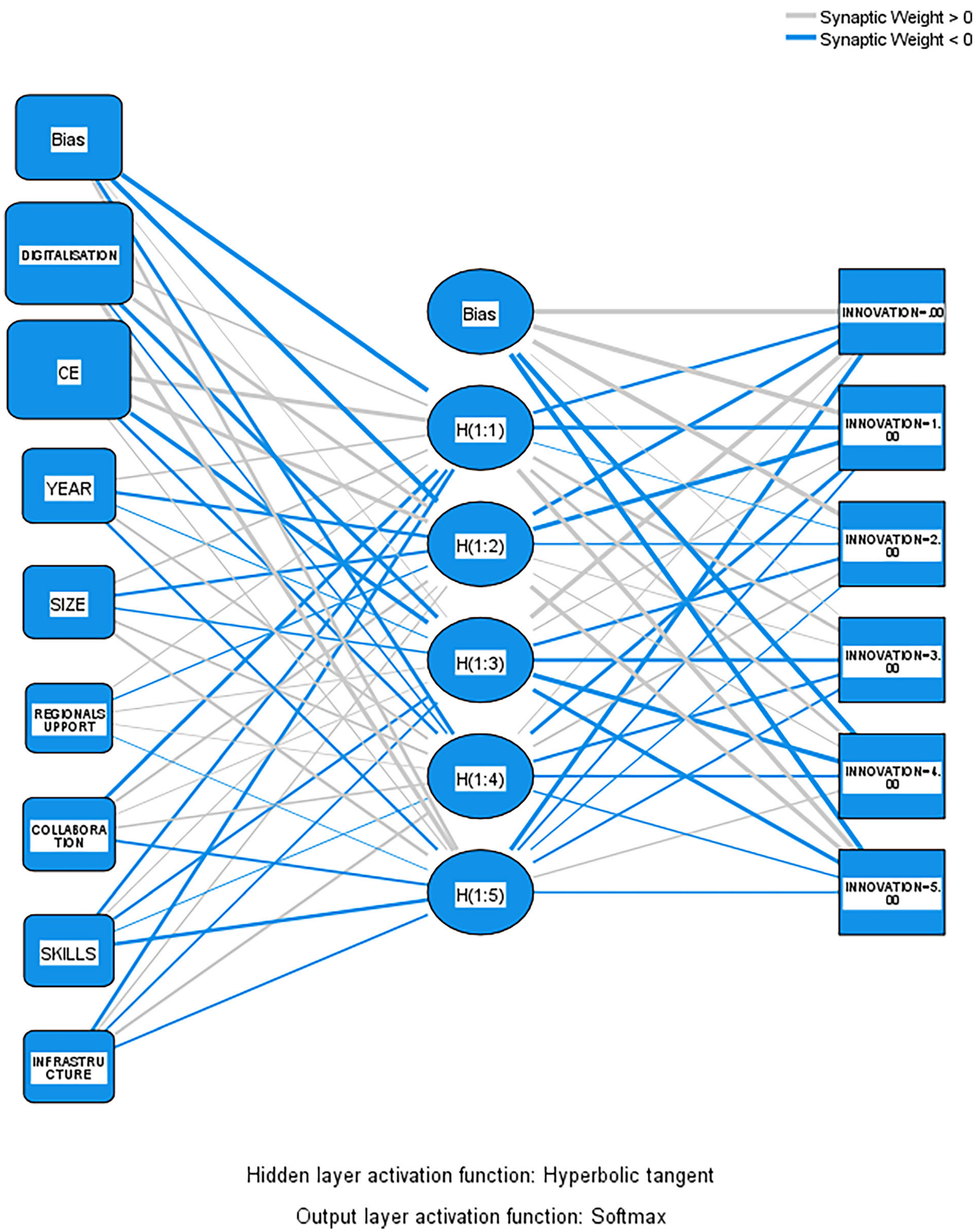

FIGURE 1 ANN-MLP architecture.

adopted and CE actions carried out. Therefore, digitalisation and CE strategic orientations can coexist with a differential level of integration in SMEs, corroborating the Hypotheses.

Regarding Hypothesis 2, which relates to how the integration of digitalisation and CE strategies affects the innovation of SMEs, we investigate whether there are differences between the various clusters, in terms of developing innovation. We previously presented the descriptive results of the innovation variable, and as shown in Table 10, we observe that companies engage in product, process, organisational, commercial and environmental innovations.

FIGURE 2 ANN-MLP simulation. Normalized importance of input variables in the innovation of SME. ANN-MLP simulation: 8-5-1 nodes per layer. Activation function (hidden layer: hyperbolic tangent; output layer: Sofmax).

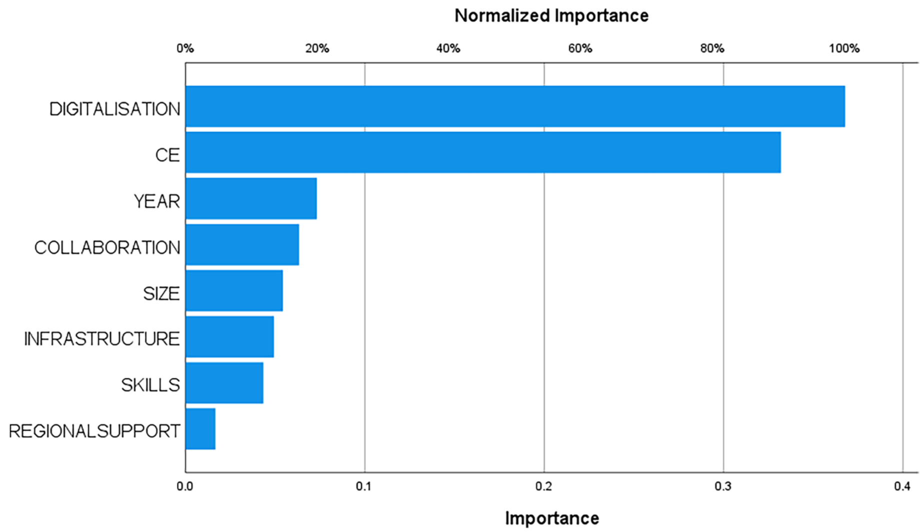

TABLE 7 Cluster distribution.

	N	Percent
Cluster 1	5719	34.9
Cluster 2	7070	43.2
Cluster 3	1653	10.1
Cluster 4	1923	11.8

Table 11 displays the result of the analysis. For this, we use the ordinal logistic regression model as the econometric model. As a dependent variable, we use innovation, and the independent variable is cluster membership as a categorical variable, corresponding each category to each cluster, following the methodology of the previous hypothesis. For the analysis of the results, the various regression coefficients must be interpreted as follows: The regression coefficient value 0 reflects the reference category ($cluster_i$), and the rest of the regression coefficients obtained correspond to the various categories ($cluster_j$) which reflect the probability of developing digitalisation and CE together with respect to the first category. That is, H0: $ß \leq 0$ means there is a lower probability of developing innovation in $cluster_i$ than $cluster_j$, and H1: $ß > 0$ entails there is a greater probability of $cluster_j$ than $cluster_i$. Cluster 3, characterized by a moderate level of digitisation and a low level of CE integration, serves as the baseline. The findings reveal that Cluster 4 ($\beta = 1.119$; $p < .001$), which exhibits a higher adoption of both CE and digitisation strategies in SMEs, demonstrates a greater likelihood of innovation compared with Cluster 3. Conversely, Cluster 1, marked by high CE integration and low digitisation, as well as Cluster 2, displaying the lowest integration in both orientations, show diminished probabilities of innovating in comparison with Cluster 3. This is evidenced by their respective regression coefficients, Cluster 1 ($\beta = -.142$; $p < .001$) and Cluster 2 ($\beta = -1.119$; $p < .001$). Regarding the control variables, we observe that size and the business environment are favourable for innovative development; however, seniority has a negative effect. Moreover, Table 11 also shows the same analysis but disaggregated for the four types of innovation. Therefore, Hypothesis 2 is corroborated.

6 | DISCUSSION

As mentioned earlier, this paper pursues a dual objective: firstly, to examine the integration of two strategic orientations, digitalisation and CE, within SMEs as outlined in Hypotheses 1a and 1b and secondly, to assess the impact of integrating both orientations on the innovative performance of SMEs, as hypothesized in Hypothesis 2.

In light of Hypotheses 1a and 1b, our research significantly contributes to the understanding of how SMEs integrate CE and digital orientations. Our findings demonstrate that SMEs tend to prioritize one orientation over the other in their integration efforts. This insight substantiates the observations made by Ardito et al. (2020), who highlighted the challenges faced by SMEs in harmonising both orientations, especially considering their inherent resource constraints. By addressing this crucial issue, our study bridges a critical gap in the existing literature. We shed light on the strategic choices made by SMEs, emphasising the prioritisation of one orientation while relegating the second orientation to a reactive role or seeking synergies between them. This strategic focus allows companies to concentrate their limited resources on the prioritized orientation, leading to more effective integration. Our research, therefore, not only corroborates the challenges identified by previous scholars but also offers valuable insights into potential solutions. SMEs, faced with resource limitations, can make informed decisions by strategically allocating their resources to the priority orientation, thereby optimising their integration efforts. In addition to our findings on SMEs' orientation prioritisation, our research reveals an intriguing asymmetry in the synergistic and complementary effects resulting from the integration of both CE and digital orientations. This observation adds a nuanced layer to the existing literature on the complementarities between innovations, as explored by Arranz et al. (2019). Previous studies in this domain have

TABLE 8 ANOVA analysis.

		Sum of squares	df	Mean square	*F*	Sig.
DIGITALISATION	Between groups	26,019.803	3	8673.268	18,793.893	.000
	Within groups	7550.502	16,361	.461		
	Total	33,570.306	16,364			
CE	Between groups	3516.439	3	1172.146	662.165	.000
	Within groups	28,961.795	16,361	1.770		
	Total	32,478.234	16,364			

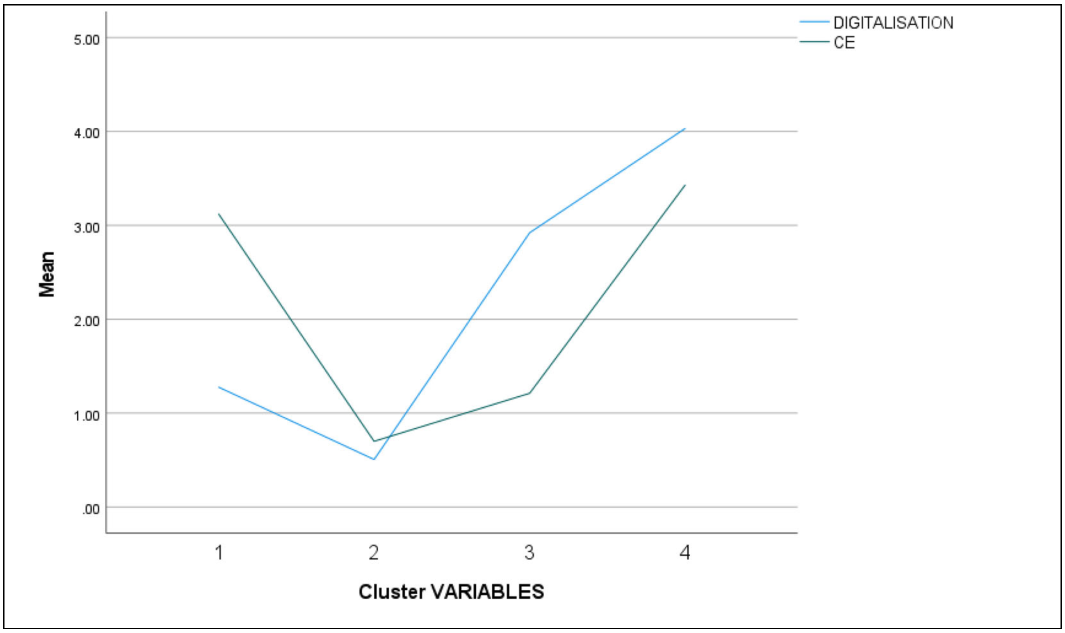

FIGURE 3 Profiles of each cluster (mean values of CE and digitalisation).

primarily focused on elucidating the mechanisms driving synergistic effects. These works have illuminated how competencies, resources and organisational routines necessary for innovation implementation can be shared, leading to economies of scale, scope and reduced time. Our research, however, investigates deeper, unveiling the asymmetrical nature of the synergistic effects emerging from the integration of CE and digital orientations. While digitalisation indeed generates synergies, easing the integration of CE efforts, this phenomenon is not reciprocated. The integration of sustainability does not, in turn, yield synergies that facilitate the integration of digital orientation. This asymmetry challenges conventional notions about the mutual benefits derived from integrating different orientations within organisations. Our study prompts a re-evaluation of existing frameworks, offering fresh perspectives on the intricate dynamics at play when harmonising diverse organisational priorities.

Regarding Hypothesis 2, which analyses how digital integration and CE orientations affect the innovative development of SMEs, firstly, the results reveal that the probability of innovating depends on the degree of development of both orientations in SMEs. Thus, we observe that the group of companies with a high level of development and integration of both orientations has a greater probability of innovation. This aligns with prior research that highlights the positive relationship and complementarity between digital and CE capabilities in innovative development (Fagerber, 2018; Arranz et al., 2019), with the probability of innovation decreasing as the degree of integration of both strategic orientations decreases. Moreover, our study uncovers a distinctive impact on the degree of innovation contingent upon whether digitalisation or CE takes precedence as the strategic orientation. Notably, when digitalisation assumes the leading role regarding CE, it leads to higher levels of innovation. Conversely, when CE is prioritized over digitalisation, the effect on innovative development in SMEs is comparatively diminished. This intriguing phenomenon can be rationalized by considering the inherently social nature of environmental practices, as previously indicated by De Marchi (2012). De Marchi (2012) highlighted the concept of the double externality of sustainability, underscoring that while the adoption of environmental practices presents disincentives for companies due to internal costs associated with their implementation, the social character of these practices allows them to be embraced without necessitating substantial internal innovations. Consequently, the prioritisation of CE,

TABLE 9 Profile of each cluster (size, sector, digitalisation and CE).

Variables	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Size				
1–9	62.6%	68.4	53.5	42.0
10–49	22.6%	20.7	25.7	27.2
50–249	14.8%	11.0	20.8	30.8
Sector				
Manufacturing	18.7%	18.2%	20.3%	25.7%
Wholesale and retail trade, repair of motor vehicles.	28.5%	28.7%	23.4%	25.3%
Digitalisation				
AI	.01	.01	.19	.42
Cloud computing	.54	.25	.78	.88
Robotics	.03	.01	.22	.40
Smart devices	.28	.08	.59	.73
Big data	.04	.02	.44	.65
High speed	.36	.01	.62	.76
Blockchain	.00	.00	.09	.19
CE				
Recycling or reusing materials	.88	.32	.47	.91
Reducing consumption	.87	.13	.28	.90
Saving energy	.85	.17	.29	.71
Developing sustainable products or services	.52	.08	.17	.93

TABLE 10 Descriptive analysis of innovation variables.

Innovation	Companies	
A new or significantly improved product or service to the market (*product*)	4561	27.9%
A new or significantly improved production process or method (*process*)	3231	19.7%
A new organisation of management or a new business model (*organisational*)	2665	16.3%
A new way of selling your goods or services (*commercial*)	3440	21.0%
Total	**16,365**	**100.0%**

characterized by its strong social and environmental ethos, might not stimulate internal innovation to the same extent as digitalisation. In contrast, digitalisation, with its focus on technology-driven advancements, inherently triggers internal innovation processes within organisations. This nuanced understanding of the relationship between strategic orientations, innovation and the social context of environmental practices contributes valuable insights to the literature. It underscores the complex interplay between organisational priorities and the sociocultural factors shaping innovative trajectories, shedding light on the multifaceted nature of innovation within the context of sustainable business practices.

Moreover, the results have classified SMEs into four distinct clusters based on their integration of digital and CE orientations and their level of innovation, as illustrated in Figure 4. These classifications provide a nuanced understanding of SME strategies in the context of digitalisation, CE practices and innovation. Below, we detail each cluster and its unique characteristics:

Cluster 4: digital circular innovators.

This cluster encompasses SMEs that excel in both digitalisation and the implementation of circular economy principles. The name reflects their high levels of innovation and successful integration of digital technologies with sustainable practices. Contrary to earlier literature suggesting resource constraints and conflicting objectives hinder coexistence, our findings align with studies indicating that integrating innovation strategies generates synergies and economies of scale (Arranz et al., 2019; Fagerber, 2018). Moreover, our results provide empirical evidence supporting previous research demonstrating the positive impact of digital technologies on product and process sustainability, reducing energy consumption and promoting cleaner practices (Bag et al., 2020; Bai et al., 2020; Lopes de Sousa et al., 2018).

Cluster 2: traditional linear practitioners.

This cluster represents companies with limited adoption of digitalisation and circular economy principles. The name underscores their reliance on traditional linear business models, lacking focus on the CE model. Positioned in quadrant 1 with low levels of both orientations, these SMEs exhibit incipient digitalisation and a reactive approach to environmental concerns. Our findings reveal a paradoxical integration of digital and CE orientations, wherein conflicting objectives compete for company resources (Aradito et al., 2020). Despite the coexistence of these strategies, the low level of integration results in limited

TABLE 11 Regression analysis cluster and innovation.

Variables	Innovation	Product	Process	Organisational	Commercial
	Estimate	Estimate	Estimate	Estimate	Estimate
REGIONALSUPPORT	.059*** (.017)	−.037 (.022)	.087*** (.025)	.057* (.026)	.045* (.015)
COLLABORATION	.095*** (.014)	.073*** (.018)	.063** (.020)	.059** (.022)	.074*** (.020)
SKILLS	.045** (.016)	.041** (.020)	−.011	.135** (.025)	.108*** (.022)
INFRASTRUCTURE	−.014 (.018)	.040* (.009)	.062*** (.010)	−.002 (.027)	−.009 (.024)
SIZE	.119*** (.018)	.138*** (.022)	.153*** (.024)	.188*** (.025)	.138*** (.025)
YEAR	−.091*** (.022)	−.068** (.017)	−.085** (.031)	−.168*** (.032)	−.134*** (.029)
CLUSTER 1	−.142** (.052)	−.169** (.061)	−.117*** (.039)	−.122** (.052)	−.181** (.068)
CLUSTER 2	−1.164*** (.035)	−.859*** (.044)	−1.009*** (.052)	−.805*** (.056)	−.780*** (.048)
CLUSTER 3	0[a]	0[a]	0[a]	0[a]	0[a]
CLUSTER 4	1.119*** (.050)	.813*** (.056)	.794*** (.058)	.674*** (.062)	.650*** (.060)
−2 Log likelihood	20,250.099	7457.347	6535.639	6207.887	6824.739
Chi-squared	2871.359	1123.962	1155.031	763.161	703.125
Sig.	.000	.000	.000	.000	.000
Cox and Snell	.167	.069	.071	.048	.044
Nagelkerke	.178	.100	.113	.081	.068
McFadden	.065	.061	.074	.055	.044

*p < 0.05; **p < 0.01; ***p < 0.001.

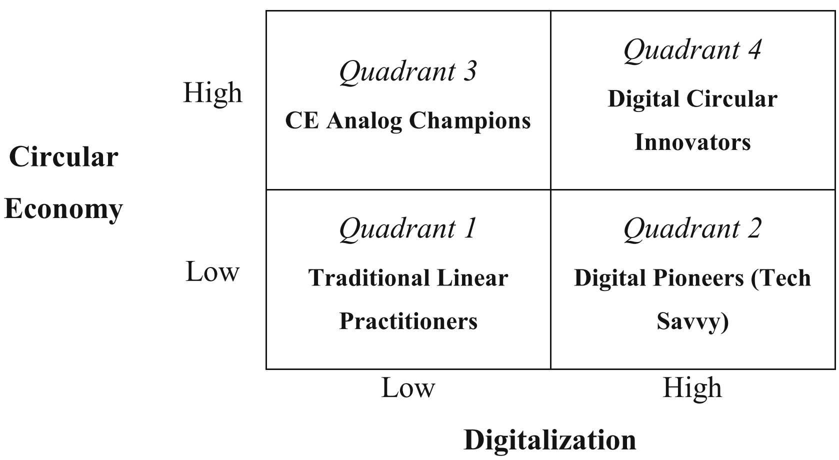

FIGURE 4 Digitalisation and CE matrix.

innovation, which may also be attributed partly to their lack of integration of digital and CE orientations.

Cluster 3: digital pioneers (tech savvy).

This cluster comprises companies that embrace digitalisation but have not fully integrated circular economy practices. The name emphasizes its leadership in digital technologies while acknowledging the need for increased CE adoption for enhanced resource efficiency and environmental compliance. Positioned in quadrant 2, these SMEs exhibit high digitalisation levels, leading to energy and waste savings in production processes. Here, CE orientation acts as a by-product of digitalisation, with a reactive environmental approach often driven by external compliance pressures rather than an internal commitment to sustainability. The high level of digitalisation characterizes this group and is correlated with a high level of innovation.

Cluster 1: CE analog champions.

This cluster consists of companies prioritising CE but with limited digitalisation, lagging in digital transformation overall compared with other clusters. The name emphasizes their commitment to sustainability, likening their approach to analogue methods, effective yet not as technologically advanced as digital solutions. Positioned in quadrant 3, these companies prioritize CE orientation with limited integration of digital technologies, such as cloud computing for data protection or traceability (Bai et al., 2020; Masood & Sonntag, 2020). In terms of innovation, the impact of CE is comparatively limited compared with digital orientation. This group is characterized as technology adopters rather than innovation developers.

7 | CONCLUSIONS

In conclusion, this study delves into the critical nexus between digital and CE orientations in SMEs and their impact on innovation. Through a large-scale analysis of data from the European Commission's Eurobarometer survey encompassing 16,365 SMEs, this research has delineated four distinct groups of companies based on the varying degrees of integration between digital and CE orientations. Our findings highlight that SMEs adept at harmonising both orientations demonstrate a significantly heightened probability of innovation, underscoring the pivotal role of integration in driving inventive processes within companies.

From a theoretical perspective, our study significantly contributes to the existing body of knowledge in strategic orientations and innovation theory. First, literature has delved into the typologies of strategic orientations, encompassing areas such as market, technology and entrepreneurship, while emphasising the development of resources and capabilities tailored to each strategic orientation (Gatignon & Xuereb, 1997; Narver & Slater, 1990; Zhou et al.,). However, the integration and interplay of digitalisation and CE strategies within companies have remained relatively unexplored. This research gap forms the focal point of our study, which comprehensively investigates the integration of digital and CE orientations specifically within SMEs. In this context, our study expands the existing literature by highlighting SMEs' tendency to prioritize the integration of one orientation over the other. Furthermore, we emphasize that during the integration process, synergies and complementarities emerge, wherein one orientation facilitates the integration of the other. However, it is crucial to note that this synergistic phenomenon is not reciprocal, resulting in asymmetries within the integration dynamics. By unveiling these asymmetrical relationships between digitalisation and CE orientations, our study challenges conventional understanding, offering novel insights into how SMEs navigate the complexities of integrating these strategic orientations. This nuanced understanding not only enriches the theoretical framework in strategic orientations but also provides practical implications for businesses seeking to harmonize digitalisation and CE strategies effectively. Second, our results provide robust empirical evidence that supports previous research which highlights how the integration of the strategic orientation of digitalisation and CE has a positive effect on a company's innovation. Moreover, our research contributes to extending how two strategic orientations are integrated, understanding that integration requires consideration that this is a dynamic process, where companies may have variability in levels of integration. This is highlighted by the taxonomy created based on the cluster analysis, which reveals four distinct profiles of SMEs based on their integration of digitalisation and CE strategic orientations. This provides empirical evidence for the theoretical arguments that digitalisation and CE orientations can coexist within SMEs at varying levels of compatibility and centrality. The analysis bears out this heterogeneity, categorising SMEs into groups that range from low integration of both orientations to high integration of both. This affirms that the relationship between digitalisation and CE is not uniformly antagonistic or synergistic but rather highly variable. Hence, identifying these clusters advances understanding of how SMEs navigate the integration of two rising strategic imperatives. By delineating specific integration profiles, the taxonomy offers granular insight into the multifaceted strategies SMEs employ unbalancing digitalisation and sustainability. This expands knowledge of how firms adapt their operations and business models to address these dual trends.

Moreover, our paper contributes by providing some managerial implications. Our results highlight the importance of integrating both digitalisation and CE orientations, their effect on the innovation of companies and their impact on the environment. Also, the results highlight the advantages and disadvantages of integrating both orientations, especially in the case of SMEs. That is, companies must seek the complementarities of the integration of both orientations, at the level of resources and competencies, allowing for production improvements, waste reduction and energy savings.

Lastly, our research provides some important implications for policy and policymakers. Based on the results of our study, the integration of digitalisation and CE orientation is crucial for SMEs to achieve a higher probability of innovation. Policymakers can play a key role in supporting SMEs in this process by providing incentives, resources and training opportunities to help them effectively integrate both orientations. Furthermore, policymakers can create an enabling environment by promoting digitalisation and CE, through regulations and standards that encourage companies to adopt both orientations. By doing so, SMEs will be able to enhance their innovation capabilities and contribute to achieving the unsustainable development goals, benefiting not only the companies themselves, but also the wider economy and society. Through these classifications, our study provides valuable insights into the varying strategies employed by SMEs concerning digitalisation, circular economy practices and innovation. The study indicates that firms able to jointly embrace digitalisation and CE—the “Digital Circular Innovators”—reap innovation benefits. This suggests that integration synergies exist between the two orientations. Consequently, SMEs should view these strategies as interlinked rather than independent. Meanwhile, policy initiatives and incentives aimed at advancing digitalisation, sustainability and innovation within the SME sector could be designed to actively facilitate combined adoption. These nuanced classifications not only contribute to academic research but also offer practical implications, guiding SMEs and policymakers toward informed decisions that promote sustainable practices and technological advancements within the SME sector.

The first limitation of this study is its reliance on cross-sectional data from the Eurobarometer survey. While the survey provides valuable insights into the integration of digital and CE orientations in SMEs, its static nature does not allow for a longitudinal analysis. Future research endeavours could benefit from longitudinal studies that track the evolution of digital and CE integration over time within SMEs, offering a more comprehensive understanding of the dynamics and long-term effects of these orientations on innovation. Additionally, the study focused primarily on quantitative data, potentially missing out on nuanced qualitative insights that could provide a deeper understanding of the challenges faced by SMEs in integrating digital and CE orientations. Exploring qualitative methods, such as in-depth interviews or case studies, could offer richer contextual information, enriching the study's findings.

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are openly available in European Commission, Directorate-General for Communication at http://data.europa.eu/88u/dataset/S2244_486_ENG, reference number 486.

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Not applicable.

ORCID

Marta F. Arroyabe https://orcid.org/0000-0003-3223-0268
Juan Carlos Fernandez de Arroyabe https://orcid.org/0000-0003-1451-3782

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