A Non-Financial Disclosure Analysis to explore the Role of Digitalization in Enabling Circular Business Models

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Abstract

The concept of Circular Economy has gained the attention of scholars, policymakers, and businesspeople, who see it as a novel approach for addressing the economic and environmental issues caused by the traditional linear model of production and consumption. The scientific literature suggests that companies can innovate their business model by introducing circularity elements with the support of digital technologies. However, there is a lack of empirical studies investigating how much digitalization is intertwined with Circular Economy in the strategic agenda of businesses. To address the above research gap, we focused on large companies, because of their leadership in global markets and capacity to influence stakeholders. We applied content analysis to the corporate sustainability reports of the companies included in the Dow Jones Sustainability Index Europe. Our results show that the connection between digitalization and Circular Economy is still poorly reported and accounted by large European companies, Despite the recent interest towards Circular Economy - especially in some specific industries - a finalized and organic discussion in the strategic-organizational dimension for designing and implementing circular Business Models does not yet emerge in a clear way.

Keywords: Non-financial Disclosure, Circular Business Model, Digitalization, Sustainable Reporting

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1. Introduction

Circular Economy (CE) has recently become popular among politicians and businesspeople thanks to the work of global think tanks and foundations, such as the Ellen MacArthur Foundation. This concept has been mainly developed by practitioners and businesses and it assumes that the traditional linear model of production and consumption is not sustainable (Korhonen et al., 2018). While this idea is straightforward, a common definition of CE is lacking and some scholars claimed that the connection with other concepts, such as sustainability, is not strong enough (Kirchherr et al., 2017). Nevertheless, both small and large companies are developing a series of actions and initiatives which can be labelled as 'circular business model initiatives' and report them in their non-financial disclosure (Guidi et al., 2024; Milne et. Al, 2009). Indeed, by adapting their business models (BMs), companies can effectively translate circular economy principles into tangible and concrete business practices to address the pressing need for a transition, as demanded by policymakers, consumers, and stakeholders at large. Consequently, for companies - to legitimize themselves (O'donovan, 2002) and increase transparency (Quattrone 2021) it becomes essential to report on their progress in this area, with the sustainability report being the conventionally used tool for such purpose (O'Dwyer et al., 2004).

BMs describe the (architecture of) organizational activities which lead to the creation, delivery, and appropriation of value (Teece, 2010). Companies can innovate their BMs to succeed in competitive business environments and become more profitable (Foss and Saebi, 2017). Circular economy business models (CE-BMs) can be seen as business architectures whose principles and practices enable to incorporate CE into the BM (Pieroni et al., 2019). Bocken and Ritala (2022) have described how companies can launch initiatives for CE using different approaches, and they have pointed out that such approaches might have both benefits and drawbacks. According to them, there are six ways to develop a CEBM, and they mainly depend on the innovation strategy adopted by the company (open or closed) and its resource strategy (focusing on narrowing, slowing, or closing the loop). Recent studies have investigated how small and medium enterprises (Bassi and Dias, 2019) and large companies (Parida et al., 2019) adapt their BM to move towards circularity. These studies have highlighted the existence of a key driver for CEBMs: digitalization, or the use of digital technologies, also because 'the introduction of digital technologies and connected objects have the potential to reduce resources use and facilitate circular systems' (Antikainen et al., 2018, p. 46). Digital transformation can indeed support value added creation and performance because of the focus on efficiency in resource utilization (Bronzetti et

al., 2024; Vitale and Cupertino, 2024). Smart solutions can be found for the renewal of the productive line and the distribution system; technologies can help to collect data both from the productive and the consumer side and use such data to reduce inefficiencies and wastage. Scholars have recognized the importance of investigating the link between digitalization and CE (e.g. Chauhan et al., 2022) which to date is mostly treated as potential also due to the critical barriers this connection is facing (Agrawal et al. 2023). Indeed, most of the literature on the topic is theoretical and yet little is known empirically about the use of digitalization to move towards CEBMs. Moreover, it is unclear if there are industry specific patterns of digitalization diffusion (Chauhan et al, 2022), and whether the use and application of digital technologies is truly embedded into their CEBMs. This leads to the following research questions: Whether and to what extent digital technologies enable the transition towards CEBMs in large listed European companies, and whether there are any industry-specific differences? This study investigates the strategic behavior of large companies through the analysis of their non-financial reporting; CE is usually led by these players, because of their capacity to influence global industry dynamics and other stakeholders as well (Ritala et al., 2018). We use content analysis to map the conceptual networks emerging from the corporate sustainability reports published by the companies included in the Dow Jones Sustainability Index Europe. In these reports, companies disclose initiatives related to the three pillars of sustainability—environmental, social, and economic—and provide details on how these initiatives are being implemented. Consequently, if digitalization plays a role in driving or supporting these initiatives, it is expected to be reflected in the reports. Our study is not the first to utilize these documents as a source for examining the integration of digitalization into companies' activities (Diener and Špaček, 2020; Leitoniene and Kundeliene, 2021; Ricci et al. 2020). Moreover, previous studies have adopted this approach in the same research context, i.e. corporate strategies for sustainability, innovation, circularity, and digitalization: Amini et al., 2018; Chavan et al., 2023; Di Vaio et al., 2024a; Jayarathna et al., 2022. Through content analysis we created different networks for the different industries included in the Index: this allows to understand in depth if there are similar (or different) patterns across industries. In this vein, our study provides a novel view on similarities and differences between the strategic approaches of large European companies to develop digitally supported CEBMs supported by digital technologies.

2. Literature review

2.1 The Circular Economy paradigm

The global environmental challenges faced by society, require the transition to more sustainable solutions. CE is gaining growing attention by policymakers and businesspeople, and it has become central in the academic debate (Stahel, 2016). CE is an emerging paradigm defined as 'a regenerative system in which resource input and waste, emission, and energy leakage are minimized by slowing, closing, and narrowing material and energy loops' (Geissdoerfer et al., 2017, p. 759). The term CE was first introduced and defined by Pearce and Turner in 1990, even if their work was inspired by Boulding (1966), who stressed the finite nature of resources and proposed the concept of closed system, i.e. an economic system in which the limited stock of resources is reproduced and made unlimited. This paradigm, differently than the traditional linear economy pattern (take-make-dispose), proposes the implementation of an approach in which the value of products, materials and resources is maintained in the economy as long as possible (Stahel, 2016). Indeed, resource constraint is affecting the human society worldwide, and it represents one of the main problems of this era because of its economic and social consequences. To tackle this problem, policymakers have introduced CE into national and international regulation, primarily targeting large enterprises (European Commission, 2015), which serve as drivers of the circular economy, also influencing smaller businesses. As a result, companies have become more interested in the idea of circularity in business (Linder et al., 2016)."However, a clear understanding of what CE really means in business is still lacking. Since the first use of this term, there have been several attempts to define the idea of circularity (Bocken et al., 2016; Ellen MacArthur Foundation, 2013; Geissdoerfer et al., 2017), and there is still disagreement about the main aspects characterizing this phenomenon. Namely, CE is frequently identified with recycling activities (Ghisellini et al., 2016), which are only a fraction of the possible circular solutions available. Furthermore, there is no agreement about the relationship between CE and sustainability (Stewart and Niero, 2018), which has been one of the main strategic drivers for businesses in the last two decades (López et al., 2017). CE focuses more on the economic and environmental dimensions, but it concentrates less on the social one, mainly looking at job creation (Mitchell, 2015) and inter-generational equity (Murray et al., 2015). All these elements contribute to the lack of clarity, from a business perspective, about what exactly is needed to adopt and implement a circular strategic approach. At the same time, there is empirical evidence that companies are willing to introduce circularity elements in their strategy because they see economic opportunities despite the higher business risk (Linder and Williander, 2017).

2.2 Towards circular business models – and the use of digitalization

CE requires companies to rethink the way they generate and deliver value, and these changes can be analysed under the BM lens (Magretta, 2002). Indeed, CE represents one of the most recent evolutions of the BM construct (Boons et al., 2013; Geissdoerfer et al., 2017) and moving towards a CEBM is considered a significant business shift (Bocken et al., 2016). According to Zott and Amit (2010; p. 2016) a BM [is] a 'system of interdependent activities that transcends the focal firm and spans its boundaries' and it provides all the information needed to understand how a business creates value not only relying on its own activities but also by considering a variety of interdependent actors. BMs can be seen as the main (intangible) architectures of a company, comprising its organizational and financial elements. An increasing number of studies suggests that sustainable transition necessitates BM innovation (Foss and Saebi, 2017) which is a pre-requisite and a transformational process towards circularity (Bocken et al., 2016; Pieroni et al., 2019). BM innovation is defined as the process by which a company deliberately changes its core elements and its business logic (Bucherer et al., 2012) to make them fit for the future. Thanks to BM innovation, companies identify and adopt novel business opportunities (Teece, 2010) and can address the demand for environmentally sustainable approaches and products coming from the society (Schneider, 2019).

In this vein, scholars and businesspeople are increasingly looking at the inclusion of CE elements into BMs (e.g. Bocken and Ritala, 2022; Urbinati et al., 2017), leading to the emergence of the CEBM concept in the business field. According to Lüdeke-Freund et al. (2019), CEBMs are a subset of the so-called sustainable BMs, that characterize organizations whose vision is declined in terms of social, environmental, and economic outcomes (Stubbs and Cocklin, 2008). Sustainable BMs aim towards the creation of positive impacts (or the reduction of negative impacts) for the environment and the society, by revising how organizations create, deliver, and capture value (Bocken et al., 2013). CEBMs, instead, aim to create value via eco-design or cleaner production; a key feature of these models is the presence of closed loops in the production and transformation processes, similarly to the idea of closed-loop supply chains (Linder and Williander, 2017; Lüdeke-Freund e al., 2019). There are many ways to achieve CEBMs and usually the transition is not radical, but it is characterized by a gradual approach (Gusmerotti et al., 2019) which includes a variety of alternative solutions, roadmap, and tools. Several studies have highlighted the role of collaboration to achieve CE (Senaratne et al., 2023) both across sectors (Kholer et al, 2022) and within the supply chain (Zucchella and Previtali, 2018) and to accelerate the tran-

sition to CEBMs (Brown et al., 2021; Hina et al. 2021). Kholer et al. (2022) highlight the potential of cross-sectoral collaboration for advancing CE, and other scholars explored the implementation of CEBMs by focusing on collaboration within the supply chain (Zucchella and Previtali, 2018) or by adopting a business ecosystem approach (Konietzko et al., 2020). Since a single company cannot effectively run a closed CE independently (Winkler, 2011) the transition 'requires the transformation of BM components and in-depth changes in all ecosystem entities' (Asgari and Asgari, 2021).

In this scenario, digital technologies (also referred to as 'emerging digital technologies' or 'new digital technologies') play an important role in the implementation of CEBMs (Khatami et al., 2023), as discussed in recent studies framing the interplay between new technologies and CE (Rejeb, 2022). To date, a clear definition of the term "digital technology" does not exist in management literature. However, Nambisan (2017) stated that it manifests in the form of three distinct but related elements: digital artifacts (digital components, applications, or media content that are part of a new product or service and provide additional functionalities), digital platforms (sets of services and architectures that serve to host complementary offerings), and digital infrastructures (digital technology tools and systems, such as data analytics or 3D printing). Di Vaio et al. (2024c) stated that 'digitalization is the use of digital technologies to change the operational processes, thus providing new revenue- and value-producing opportunities". Digital technology is considered a key factor in the development of CE, because its advancements offer many opportunities and facilitate new BMs ideation, implementation and incremental improvements such as the transition to servitisation strategy (Rapaccini et al. 2023). Indeed, 'digital innovation facilitates the development or diffusion of innovative technologies, combined with the adoption of revolutionary practices, processes or management services' (Del Giudice et al., 2022, p: 19). For example, digital technology application significantly smooth strategic alliances and integration along the supply chain and help in managing supply chain risks (Yuan and Pan, 2023).In this regard, big data analytics can facilitate the collaboration and information exchange among multiple stakeholders to maximize the resource utilization and resource yields (Gupta et al., 2019) and digitals are useful to foster waste recovery by creating connection along the supply chain (Ciulli et al., 2019; Visconti 2020). Moreover, IoT and Artificial Intelligence play a key role in the transition toward circularity supported by novel BMs (Chauhan et al., 2022) and researchers stressed the importance of IoT in reuse, remanufacturing and recycling activities (Rejeb et al., 2022). Then, blockchain, big data, robotics, and 3D printing enhance the transition to circularity because they enable companies to reduce the use of resources, improving transparency and traceability, and empowering the development of new ideas

(Ajwani-Ramchandani et al., 2021). Thus, such digital technologies have both the potential to renew firm's back-end operations (changes in the production processes) and front-end operations (changes in the value logic) (Ancillai et al., 2023). Namely, digital technologies and related capabilities (Chaudhuri et al., 2022) have the potential to translate the CE theoretical principle into practice (Antikainen et al., 2018) and developing a set of different strategies to concretize the transition to circularity (Liu et al., 2022). However, despite authors such as Agrawal et al. (2022) argue that digital solutions could support the operation of CEBMs or Liu et al. (2022) which indicates those functions that are more mature in terms of potential implementation of CE only in recent years this phenomenon has started to be investigated more in depth, and there is a lack of empirical studies focusing on whether and to what extent companies use (or declare to use: since sometimes there is a risk of circularity greenwashing when promoting or implementing specific corporate strategies - see Yamoah et al., 2022) digital technologies for enabling CEBMs (Rejeb, 2022). This study contributes to filling this gap by examining how large companies, which play a crucial role in driving the transition to circular business models (Bocken et al., 2017), leverage digital technologies to enable and support this shift.

3. Data and Methods

As source of data, we use the corporate sustainability reports from the companies included in the Dow Jones Sustainability Index Europe. The DJSI is widely recognized as a leading indicator for corporate sustainability. Companies included in this index are selected based on an evaluation of their Environmental, Social and Governance performance (Clarkson et al., 2019; Cunha et al., 2019). This selection is conducted by S&P Global through a Corporate Sustainability Assessment, which benchmarks companies within their industry and applies a best-in-class approach to select top 10% sustainable top performers (S&P Global, n.d.). Indeed, The Index is suitable for a cross-sectoral analysis because it adopts a selection policy of including the best companies from all industrial sectors (Fowler and Hope, 2007); moreover, it relates to the concept of CE because, as suggested by Opferkuch et al. (2022, p. 440), it enables to 'identify companies who are recognized as frontrunners for their sustainability performance' and focus on CE initiatives to address CE-related regulations established by the European Commission. Sustainable reporting describes the corporate social responsibility policies and initiatives implemented by each company, providing an overview of the company's strategy on the three sustainability dimensions (Ciccola et al., 2022); moreover, they include additional information that complement the

company's financial statement. We chose to rely on sustainability reports due to their official nature, which enhances the reliability of the information they contain. Overall, we analyzed reports from 104 different companies operating in 12 different industries and based in 15 countries[1](Table 1). At the time of data collection, the Dow Jones Sustainability Index included 149 companies. To ensure a representative pool of reports for each sector, we excluded industries with fewer than six companies listed in the Index, as their limited representation would not provide meaningful insights. This narrowed our sample to 106 companies. Of these, we searched for sustainability reports and successfully retrieved 104, as reports for two companies were not available.

Number of sustainability reports by sector		**Number of sustainability reports by country**	
Sector	**N°**	**Country**	**N°**
Banks	9	Austria	2
Capital Goods	15	Belgium	2
Diversified financials	9	Denmark	1
Energy	6	Finland	4
Food, Beverage & Tobacco	8	France	13
Health Care Equipment & Services	5	Ireland	1
Insurance	9	Germany	8
Materials	12	Italy	9
Media & Entertainment	6	Netherlands	7
Pharmaceuticals, Biotechnology & Life Sciences	7	Norway	3
Real Estate	9	Portugal	2
Utilities	9	Spain	12
		Sweden	6
		Switzerland	12
		United Kingdom	22
TOT	104	TOT	104

Data collection was carried out between January and February 2023. At that time, the most recent sustainability reports available were those referring to the

[1] Non-EU countries such as Switzerland and Norway have similar approaches - when it comes to mandatory climate reporting - to EU countries (see Alexander and Darbellay, 2024, and Ottenstein et al., 2022); in this vein, we do not expect strong differences in their approach towards transparency and disclosure.

fiscal year 2021, published during 2022. For consistency, we selected reports from 2021 across all companies, even in the few cases where 2022 reports were already available. The reports were collected by reviewing company websites and downloading them directly; in some cases, the Corporate Register portal was used to facilitate access. Previous research used stock market indexes for defining the population of companies to be investigated (Bocken et al., 2017; López et al., 2017; Ritala et al., 2018). This approach is particularly indicated because it allows defining a heterogeneous group of actors whose data are publicly accessible; moreover, these companies are global players with the capacity of influencing other stakeholders and the global economy as well (Ritala et al., 2018). The Dow Jones Sustainability Index construction methodology is particularly suitable for studying large companies, but it is less representative for small and medium companies (Fowler and Hope, 2007). Because the Dow Jones Sustainability Index Europe is based on corporate economic, environmental, and social metrics, all the companies included in this Index are considered sustainability leaders and particularly keen on environmental aspects. Furthermore, they are considered innovative companies, and their interest in innovation, digitalization and digital technologies is well documented in the literature (e.g. Gallego-Álvarez et al., 2011). We have been able to collect data - i.e. reports - from 70% of the companies included in this Index, which is considered a good coverage (López et al., 2007).

The software Leximancer (version 4.51) was employed to perform automated content analysis on the identified documents and to produce related concept-maps. Leximancer allows to conduct both a semantic and relational analysis of the text through its impartial elucidation (Di Vaio et al., 2024b; Smith and Humphreys, 2006). Namely, the software is capable to identify both the salient concepts in a body of text and the relationship linking them. The concept-mapping function of the software aid in interpreting the conceptual structure of texts (tsts and Bisman, 2010; Di Vaio et al., 2022) outperforming other software for textual analysis such as NVivo especially for semantic network analysis (Sotiriadou et al., 2014). Relying on machine learning and supporting automated content analysis, but with the possibility of supervision from the researchers, the software supports the analysis of large quantities of data in a relatively short period of time, mitigating the limitations associated with the analysis of large-scale textual datasets (Nunez-Mir et al., 2016). In other words, the software helps "to minimize researcher's bias often present in techniques involving manual 'handling' of data" (Wilk et al., 2021, p. 1093). The automatic detection and analysis of text-related patterns allowed to better understand if – and how – certain concepts have been discussed together or not. Moreover, this software can be used for detecting semantic patterns between concepts and themes, something difficult to achieve with a pure qualitative approach (Buzova et al., 2020). Automatic textual analysis is

therefore finding more and more applications due to its advantages when analysing large bodies of text (Nunez-Mir et al, 2016), like in the case of our research. Indeed, the software has been already fruitfully employed in sustainability research using a variety of data such as company reports of Fortune 500 companies (Amini et al., 2018), scientific articles (Massaro et al., 2021), political discourses (Ghinoi et al., 2021) and, as in our case, sustainability reports (Kim and Kim, 2017; Di Vaio et al., 2024a; Di Vaio et al., 2024b). In our study, however, the focus of the analysis is on the relationship between circularity aspects and the development of BMs rooted in (emerging) digital technologies.

Considering the exploratory nature of this study, the concept discovery was fully data driven with the only editing of the text consisting in the removal of stopwords. Leximancer produced an initial set of concepts to be used for the following phase of the learning process. Such list was checked for consistency by the researchers, and minor changes were implemented to enhance accuracy of the analysis. For example, some words were mistakenly identified as variants of the same concept (e.g. internal and international); in such cases words were separated and considered as part of different concepts (Smith and Humphreys, 2006; Sotiriadou et al., 2014). This process involved three of the researchers: two of them (called "controllers") independently produced two equally structured files with their comments and suggestions to the initial set of concepts. Crosschecking is a key reliability check in qualitative analysis (Franklin et al., 2010), and this applies to our research as well. Then, a third researcher (called "arbitrator"), revised these files to identify discrepancies and to address any discrepancy. In ambiguous cases, the fourth researcher was involved to check the decision taken by the arbitrator, in around one third of the cases, the arbitrator intervened for deciding about coding discrepancies between the controllers. Following the check and cleaning of this initial list, Leximancer was then used to generate a thesaurus and concept maps. To ensure rigor and integrity in our approach, all the maps and the related files used to support the analysis were analysed as it follows (similarly to other studies using Leximancer: see Harwood et al., 2015; Lemon and Hayes, 2020): the four researchers were divided into two groups, working separately in the first phase and together in the second one where they shared their observations with each other. Before splitting, the two groups agreed on the key points for analysing the maps consistent with the research question. Namely, the work was not divided but replicated among the two groups to increase the reliability of the analysis. Finally, following an approach similar to Di Vaio et al. (2022), we further explored Leximancer's outputs with a manual content analysis to cross-check for the meaningful relationship between digital and circular economy, since the software "does not allow the analysis of the sentences' textual logic" (Di Vaio et al., 2022, p. 12719). We chose specific keywords (waste, recover*, regener*, reus*,

repair, recycle*, remanufacture*, shar*, biomaterial*, refurbish*; material flow; eco-industrial park; end-of-life; product life; life cycle assessment; LCA, loop;) derived from existing literature (e.g. Merli et al., 2018) to determine which parts of the report were relevant for our analysis we went through the reports to identify sections and paragraphs dedicated to circular economy; we independently assess the above sections to identify specific patterns linked to digitalization; we cross-checked our results (each researcher was responsible for 26 reports). In line with the research question of this study, this investigation was aimed to identify how digitization interacts with the development of circular business models in the companies included in the Dow Jones Sustainability Index Europe. This manual check was conducted to further deepen the data analysis and to triangulate the findings with those obtained through Leximancer, aiming to identify potential discrepancies and ensure greater rigor. In this step, the identification of keywords was necessary to deeply challenge the results obtained with Leximancer. In the end, the manual analysis of all reports fully matches the results previously obtained with Leximancer and gave rise to the quotes reported in the next paragraph. Following this further check, we can confirm the robustness of the results.

4. Results

We created an overall industry map to identify general trends and individual maps for each industry to compare similarities and differences. This offers a detailed overview of approaches in industries within the Dow Jones Sustainability Index Europe.

Concepts are represented as nodes in the map, and the connection between two nodes represents their relationship, which is based on the concepts' co-occurrence in the report. Larger dots represent concepts more frequently appearing in the text, while smaller dots rarer ones. Concepts are grouped into themes, visible as bubbles, and their labels are taken from the largest node in the bubble. Such thematic bubbles are heat-mapped, which means that themes with warmer colours (orange, red, yellow) appear in text more frequently than those associated to colder colours (blue, green, purple) (Engstrom et al., 2022; Haynes et al., 2019). Maps are produces to provide a visual summary of the textual data: the researchers adopted an explorative approach in producing the conceptual maps using different parameters and carrying out checks to ensure stability of the visualizations produced and clarity of the output. In this study a topical clustering was employed, as producing more stable results. Theme size, impacting the number of thematic bubbles mapped on the visualization, and therefore readability and

meaningfulness of the map, was set at 40%. Lower values for this parameter result in more and narrower themes, while setting higher values for it will produce less themes – with 100% value leading to all concepts being included in a single thematic bubble. According to the researchers a value of 40% was optimal in terms of leading to visualizations which were both clear and non-trivial. In this section, we show. We provide in table 2 (available in Appendix C www.sidrea.it/digitalization-circular-economy) an analysis across sectors with reference to all the figures relating to single sectors available in Appendix A and data in Appendix B (www.sidrea.it/digitalization-circular-economy). In the table we also provide quotes from the manual check.

Considering all the industries, our study reveals that the concept "circular" is included in the "emission" theme, which is a domain mostly focused on environmental issues and no connection is observed with reference to the social dimension. "Circular" is visually connected only with "reducing", however, looking at other fine-grained output produced by Leximancer (Appendix B www.sidrea.it/digitalization-circular-economy) it is possible to observe other related concepts, such as "change", "climate", "sustainable", "products", "waste", and "carbon". Furthermore, we noticed that the colour of the bubble is light green, which indicates a marginal presence of this concept in all the reports. Indeed, even if we are examining reports that are supposed to concentrate on sustainability and other elements linked to environmental awareness, the predominant themes in the network are "risks" and "services". Finally, it is under the "services" theme that we notice the presence of "digital", which shows a connection with the "services" concept (the one naming the bubble/theme) but not with "circular". When looking at all the connections with other concepts (Appendix B www.sidrea.it/digitalization-circular-economy), not just those more relevant in terms of co-occurrence, we can see that "digital" is connected with "customers", "technology", "solutions" and "data", but the likelihood of connection with "circular" is very low.

5. Discussion

This research investigates whether and to what extent large listed companies, committed to sustainability, leverage on digitalization to design and implement BMs oriented to CE, by offering a cross sectoral analysis. Recent literature has highlighted that the diffusion of CE can be driven by the ability of companies to design new BMs (Bocken et al., 2016; Centobelli et al., 2020) and digitalization has been recognized as a key enabler of CEBMs (de Sousa Jabbour et al., 2019). However, although the literature exalts digitalization for the transition to CEBMs

alternatives to linear ones, its employment is still very limited (Schöggl et al. 2023) or continues to be treated merely as potential (Agrawal et al. 2022; Liu et al. 2022). Previous research so far has yielded limited empirical evidence of how firms leverage digitalization to innovate their BMs towards the CE, thus remaining predominantly conceptual (Centobelli et al., 2020; Rajala et al., 2018). This paper contributes to the literature on the CE in large companies (Bocken et al., 2017).Our study contributes to filling this research gap by examining the official statements made by large listed companies in their Sustainability Reports. By focusing on the European companies listed in the Dow Jones Sustainability Index Europe, we analyse how these companies employ digitalization to implement CEBMs. This approach places this research within the framework of those studies that, using secondary sources and in particular sustainability reports, examine the integration of digitalization into the company's activities (Diener and Špaček, 2020; Leitoniene and Kundeliene, 2021; Ricci et al. 2020). In this case, positioning the study within the field of sustainable business model through digitalization (Ancillai et al., 2023) and contributing to the knowledge on CEBMs. Through the examination of sustainability reports, our findings reveal that this connection remains relatively weak, serving as a clear signal of the challenges and gaps in effectively leveraging on digitalization to transform the BMs. Our research extends the existing body of knowledge by moving beyond the predominantly conceptual discourse and providing an evidence-based analysis of the intersection between digitalization and CEBMs in large listed companies. Furthermore, this study nourishes and advances the theoretical debate on how diverse industries view application off digitalization to innovate the BM towards CE.

5.1. How far have large listed companies leveraged digitalization to innovate BMs towards the CE according to their non-financial disclosure

This work provides empirical evidence about how widespread and pervasive is the link between digitalization and CEBMs is in large listed companies non-financial disclosure. Thus, we help lift the veil on the progress of the ongoing transition to CEBMs. A main insight from this research is that, despite the growing emphasis in the debate involving scholars, practitioners and policymakers, the connection between digitalization and CE is still largely absent in their storytelling of how they develop and implement BMs.

The general trend emerging from the map representing all industries shows that CE is still scarcely mentioned, and it is linked almost exclusively to concepts referring to specific initiatives or aspects concerning the environmental dimension (see also Appendix B www.sidrea.it/digitalization-circular-economy). CE is used in connection with initiatives such as emission reduction, recycling or waste

reduction, climate, and water consumption, and there are no links to social issues. Consistently with Geissdoerfer et al. (2017) and Murray et al. (2017), our results confirm that CE is mainly related to the environmental dimension of sustainability and mostly exclude the integration of social aspects. The practical application of the CE principles continues to be related to the waste management dimension and, consequently, to the recycling activities, as revealed by Ghisellini et al. (2016). The connection of the "circular" concept with other concepts that belong to the environmental domain identifies an essential, but basic connection. At the same time, with few exceptions, "digital" does not frequently appear to "circular" or, more in general, to "sustainability". "Digital" is mainly connected to concept that belong to human resources management domain (e.g. "work", "training", and "learning"), to customer management domain (e.g. "services", "client", "customers"), or to "product management" domain (e.g. "productivity", "industrial", "processes") (see Appendix B from table 27 to table 39 www.sidrea.it/digitalization-circular-economy). This does not mean that digitalization does not have the potential to facilitate companies in the transition towards CEBMs, but that its adoption, to date, does not appear to be explicitly aimed at achieving this purpose. Namely, although the data show widespread use of a range of digital technologies by the companies in the sample, a coherent and organic inclusion in the strategic-organizational dimension for designing and implementing CEBMs does not emerge.

As a matter of fact, there are companies that, through digitalization, are implementing initiatives that enable convergence towards the CE, but currently cannot be considered foundational of their strategy and CEBMs. Our results are consistent with Schöggl et al. (2023) which found a low degree of implementation of digital technologies for sustainability and CE; indeed, it seems that in their disclosure of non-financial statements companies do not specifically concentrate on the employment of digitalization to create CEBMs. This generates a need for future research to study the effects that technological advancement and digitalization have on existing BMs, even when they are not intentionally implemented for shifting towards new (circular) business models (for instance, in case of merely improvements of processes' efficiency). Thus, we highlight the importance of examining the impact of digitalization on this transition, even when not directly and strategically meant to do that.

The lack of integration between the innovation of CEBMs and digital technologies highlights an ongoing process of technological regime shift. As observed in the previous literature on sustainable innovation (Kemp et al., 1998), the introduction of radical technologies may be hindered or slowed down by a multiplicity of elements, including long development times, the magnitude of costs and investments, uncertainties about market demand and social gains, as

well as the need for change at different levels in the organisation, infrastructure and, more generally, the social and institutional context. Overcoming these difficulties is facilitated by special support efforts with a societal embedding component (Kemp et al., 1998). Likewise, the integration of digitalization in the process of BM innovation towards circularity shows the characteristics of a technological regime shift.It could be accelerated through a more extensive involvement and support of social, economic and institutional actors, through training for skills development, access to technological infrastructures, investment support, and the propensity to collaborate and project in an open innovation perspective (Bocken and Ritala, 2022; Jesus and Jugend, 2023) that would foster the design and implementation of CEBMs driven by digital technologies (Henry, 2020).

5.2. Industry specificities and different level of advancement

The intertwin between digitalization and CE - and consequently the ability to generate innovative CEBMs through digitalization - differs from industry to industry. Results show that large listed companies in certain industries are still going through a process in which digitalization has become central; this is particularly true in manufacturing, due to the characteristics of the products and production processes. In such industries, e.g. in the capital goods industry, digitalization is a key driver of BM innovation, even if it does not yet contribute substantially to the transition towards CEBMs. In other industries, especially dematerialized services (for example, banks and diversified finance), digitalization shows a slower potential to contribute to this process. These differences across industries can be explained by the formation of strategic niches that confirm the ongoing shift in the technological regime. Some industries, mainly due to the characteristics of their production processes, constitute niches where the application of digital technologies in new CEBMs can be experimented, thus fueling their development and diffusion. There are, therefore, different speeds among industries in the adoption and implementation of new business models in which circularity and digital technologies are integrated. Moreover, other industries, as showed above, contribute to the circular innovation of BMs of companies belonging to different industries through collaboration and networking activities that extend the supply chain and have the potential to lead to the formation of ecosystems. Consistent with the management of strategic niches (Kemp et al, 1998), the broadening of the socio-economic environment to a wider variety of social, economic and institutional actors can foster the speed of diffusion of radical technologies and the design and implementation of new BMs that adopt them in firms belonging to different industries. Our results highlight that companies in some industries create services or use tools which can support CEBMs of organizations belonging to

other industries (e.g. as noted in the pharmaceutical, biotechnology & life science industry). For example, the ideation of eco-friendly materials designed with sustainable resources; the development of new communication channels to share information; and the continuous adaptation of services and products portfolio to answer to these new "circular needs" and changes. Thus, we argue that the value of digitalization in creating CEBMs could lie in enhancing cross-industry collaboration between companies. This insight is consistent with the definition of a BM as a system of interdependent activities implemented by a firm and its partners (Zott and Amit, 2010) and reinforces the construct by contextualizing its application to digitalization-driven CEBMs (Antikainen et al., 2013). This provides important practical insights that highlight the importance of collaboration among companies, which will be further discussed in the conclusions.

Thus, our study addresses the request from Chauhan et al. (2022: p. 13) to advance the academic debate on 'how diverse industries view application of digitalization technologies for BM innovation, which leads to realization of CE benefit'. Industry-specific activities, structures, regulations, and know-how influence the way by which digitalization empowers the transition to CE. Our results confirm an ongoing trend (Bocken et al., 2017) but advance previous research by providing evidence about how companies belonging to different industries can leverage digitalization to innovate BM - in the transition towards a CE system. We provide empirical support to previous studies which have shown that digitalization fosters inter-firm collaboration in supply chain relationships (Burmaoglu et al., 2022; Chiappetta Jabbour et al, 2019) and represent a starting point in explaining the development of innovation ecosystems in which companies participate to access resources that do not come from the supply chain they belong to.

6. Conclusions

This research focuses on how digitalization interacts with the creation and implementation of CEBMs. Our findings suggest that the transition to a CE system is an ongoing trend that does not yet show full integration into large listed companies' strategy. The connection between CE and digitalization appears to be underexplored, indicating the need for further research to understand how integrating digital technologies into BM innovation processes could enable and accelerate the transition to CE. To address the lack of consuetude in the integration of digitalization into the strategic and organizational purposes of companies towards CEBMs and given the potential highlighted by previous literature, it is essential for the scientific community make an extra effort in identifying patterns able to

consolidate and facilitate the binomial. We also point out the existence of differences between industries: companies belonging to diverse industrial sectors develop their own strategies in creating innovative CEBMs. Analyzing these differences can be beneficial for practitioners, because it provides a better understanding of potential opportunities for inter-firm collaborations - which can explain the development of innovation networks and supply chain relationships for the design and implementation of CEBMs.

Our findings lead to the several managerial implications. By mapping the connections between concepts used by large listed European companies in their strategic reports, this research unveils the prevalence of semantic relationships that refer to specific initiatives, but at the same time shows the modest integration of digitalization into the companies' strategy. This results in a modest propensity to design and implement innovative BMs that accelerate the transition towards CE. First, as highlighted above, the integration of digitalization in the process of BM innovation towards circularity shows the characteristics of a technological regime shift that require companies to develop experimentation capabilities not only towards sustainability and the CE, as already found by the extant research but also on how digitalization can serve as an enabler in the process of BM innovation towards the CE. Therefore, the weak connection between the use of digitalization and strategic decision founding CEBMs does not deny its potential already identified by previous studies, but it enhances the need for companies to develop new capabilities to identify and exploit novel opportunities for interaction and new complementarities between digitalization and the CE leading to new BM. Therefore, large listed companies managers aiming to use digitalization for innovating their BM and making it circular should identify specific competences and organisational capabilities which can help to design a medium-term strategy; this strategy should progressively reconfigure organisational processes to exploit the full potential of digitalization. The transition towards circularity requires intense digital education and training: this can support the search for new solutions enabling the design of CEBMs. Second, companies can take advantage of collaboration with other stakeholders to access new resources or business opportunities consistently with their CEBMs. We suggest that the participation and involvement in innovation networks - and the collaboration with supply chain partners - can be key in intertwining digitalization with the creation of CEBMs. Finally, our findings have direct implications for policymakers as well. Recognizing that different industries are at different stages of the transition towards circularity, we advise that implementing policy initiatives for supporting digitalization can trigger the development of good practices in large companies, as well as on small and medium enterprises. Furthermore, policymakers can support and incentivize digitalization in intersectoral collaborations aimed at designing new CEBMs: laggards

can benefit of the relationship with companies already successful (or at an advanced stage) in using digital technologies for innovating their BM according to a CE perspective.

This research has also some limitations. First, we collected data from the sustainability reports of companies listed on the Dow Jones Sustainability Europe Index and even if previous research has already employed them to investigate companies' business model innovation (Marioka et al., 2016), further research can concentrate on gathering primary data via interviews with the companies' top managers, to corroborate the results emerging from our analysis with additional information that are not included in the reports. Indeed, companies are facing difficulties in accounting for these decision and actions as it is required increasingly complex data and forecast (Granà et al., 2024) and a comparison of the secondary data with the primary data could highlight nuances that have not been captured in this research. In addition, secondary data collection could be expanded by integrating information from company websites or social media providing greater variety of sources used to investigate companies' business model. Second, by selecting the companies listed on the Dow Jones Sustainability Europe Index, we decided to concentrate on a set of companies with specific economic and financial characteristics. The same study can be replicated by collecting data from a sample of unlisted companies or companies belonging to an Index with different requirements - to have a broader overview of the phenomenon based on a more heterogeneous dataset. Third, our study is the exclusion of sectors with a limited number of companies included, which may have restricted the comprehensiveness of our analysis. However, this choice also provides a foundation for future research, which could explore alternative data collection strategies. Finally, this study aimed to investigate whether and to what extent digital technologies enable the transition to circular business models. Future research could examine how different digital technologies, with varying usage requirements, differ in their ability to facilitate the adoption of circular business models and how these differences are influenced by industry-specific factors and contextual conditions.

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