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MAPPING CIRCULAR ECONOMY ADOPTION IN EUROPEAN SMEs FROM A BIBLIOMETRIC PERSPECTIVE

MAPOWANIE WDRAŻANIA GOSPODARKI O OBIEGU ZAMKNIĘTYM W EUROPEJSKICH MŚP Z PERSPEKTYWY BIBLIOMETRYCZNEJ

This article analyses the scale, dynamics, and thematic trends in research on the adoption of the Circular Economy (CE) among small and medium-sized enterprises (SMEs) in the European Union (EU). Its primary aim is to map influential contributions, identify research clusters, and explore the interconnections between barriers, enablers, and eco-innovation strategies that facilitate CE transitions in SMEs. The core research problem concerns how SMEs adopt CE principles and how these adoption patterns vary across strategic, technological, economic, and operational dimensions. A bibliometric analysis of publications from 2016–2025 indexed in the Scopus database was conducted using Microsoft Excel and VOSviewer. Performance analysis (of authors, journals, and countries) and scientific mapping (via bibliographic coupling and keyword co-occurrence) were complemented by comparative cluster analysis to explore synergies among different aspects of CE adoption. The findings highlight the interplay of digitalization, leadership, eco-innovation, and supportive policy in driving CE transitions in SMEs. However, certain limitations should be emphasized. Reliance on English-language publications and a single database (Scopus) may lead to the underrepresentation of studies published in national languages or disseminated through other repositories. The focus on EU-affiliated studies may also limit broader global applicability. Moreover, the bibliometric approach prioritizes quantitative results, constraining in-depth assessment of theoretical and methodological dimensions. Despite these limitations, the study deepens understanding of CE implementation processes and offers practical recommendations for policymakers, researchers, and business leaders.

Keywords: circular economy; eco-innovation; SMEs; European Union; bibliometric analysis
JEL: L2; O44; Q01; Q5

Artykuł analizuje skalę, dynamikę oraz trendy tematyczne w badaniach nad wdrażaniem gospodarki o obiegu zamkniętym (GOZ) przez małe i średnie przedsiębiorstwa (MŚP) w Unii Europejskiej (UE). Celem artykułu jest mapowanie wpływowych publikacji, identyfikacja klastrów

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badawczych oraz analiza powiązań między barierami, czynnikami sprzyjającymi i strategiami ekoinnowacji wspierającymi transformację GOZ w MŚP. Główny problem badawczy dotyczy sposobu wdrażania zasad GOZ przez MŚP oraz różnic w tych procesach w wymiarze strategicznym, technologicznym, ekonomicznym i operacyjnym. Przeprowadzono pogłębioną analizę bibliometryczną publikacji z lat 2016–2025 dostępnych w bazie Scopus, wykorzystując narzędzia Microsoft Excel i VOSviewer. Wyniki wskazują na rosnące zainteresowanie tematyką GOZ w MŚP, szczególnie po 2020 r. Zidentyfikowano cztery klastry tematyczne: (1) bariery strategiczne i szanse, (2) cyfrowe czynniki wspierające i gotowość organizacyjna, (3) ramy pomiarowe i wyzwania operacyjne, (4) czynniki ekonomiczne i wpływ polityk publicznych. Badanie podkreśla znaczenie cyfryzacji, przywództwa, ekoinnowacji i wsparcia politycznego w procesach transformacji GOZ w MŚP. Jednocześnie należy podkreślić pewne ograniczenia: analiza obejmuje wyłącznie publikacje anglojęzyczne z jednej bazy danych (Scopus), co może prowadzić do niedoreprezentacji badań publikowanych w językach narodowych lub w innych repozytoriach. Skoncentrowanie się na badaniach powiązanych z UE ogranicza również możliwość pełnej aplikacji w innych kontekstach globalnych. Ponadto podejście bibliometryczne kładzie nacisk na ilościowe wyniki, co ogranicza dogłębną ocenę jakościowych aspektów teoretycznych i metodologicznych. Pomimo tych ograniczeń artykuł pogłębia zrozumienie procesów wdrażania GOZ i oferuje praktyczne rekomendacje dla decydentów, badaczy i liderów biznesu.

Słowa kluczowe: gospodarka o obiegu zamkniętym (GOZ); ekoinnowacje; MŚP; Unia Europejska; analiza bibliometryczna
JEL: L2; O44; Q01; Q5

I. INTRODUCTION

The transition to a circular economy (CE) is widely acknowledged as a key pathway to sustainability and resource efficiency in the European Union (EU). Small and medium-sized enterprises (SMEs) play a central role in this shift due to their significant economic impact and innovation potential. Their adoption of CE practices is crucial for achieving the European Green Deal and the 2030 Agenda, as well as for enhancing firm-level performance, competitiveness, and resource efficiency across sectors and regions (Dey et al., 2022; Moric et al., 2020; Tritto et al., 2023).

However, the adoption of CE among EU SMEs remains highly uneven. This heterogeneity stems from a combination of firm-level attributes (e.g. size, sector, R&D intensity), national factors (such as GDP and waste generation), and institutional frameworks (Bassi & Dias, 2019; Segarra-Blasco et al., 2024; Tritto et al., 2023). CE practices themselves vary widely – activities like waste minimization and product redesign are more common, while others, such as water reuse or energy re-planning, are less frequently implemented (Bassi & Dias, 2019; Katz-Gerro & Sintas, 2018; Lopes et al., 2025). Understanding these patterns is crucial for developing effective policies and support instruments tailored to SMEs.

While the existing literature has addressed various aspects of CE adoption in SMEs, significant gaps remain that limit both comprehensive academic understanding and the development of effective, evidence-based policy. First, the absence of a systematic bibliometric mapping of the intellectual structure

underlying CE-SME research prevents researchers from identifying how different research streams interconnect, overlap, and evolve. Existing reviews, including the work by Ahmadov et al. (2025) and García-Quevedo et al. (2020), primarily employ narrative or systematic literature review methodologies that synthesize thematic content but do not reveal the underlying knowledge architecture or intellectual networks shaping the field's development. Second, while earlier works such as Rizos et al. (2016) and Kiefer et al. (2019) provide valuable insights into specific barriers and drivers, they represent static snapshots of the field rather than dynamic mappings of its evolution. Third, existing reviews lack systematic identification of multidimensional thematic clusters and their interconnections within the specific socio-economic and regulatory context of the EU. Although García-Quevedo et al. (2020) examined barriers across European SMEs, and Bassi & Dias (2019) offered comparative insights, no study to date has employed bibliometric clustering techniques to reveal how environmental, technological, economic, and operational dimensions interact within the scholarly discourse on CE-SMEs in Europe. This gap is critical, given that CE adoption is inherently a cross-domain phenomenon that spans environmental performance, operational management, business model innovation, and institutional frameworks.

Thus, by leveraging bibliometric methods, this study aims to provide a nuanced understanding of how SMEs across the EU engage with the circular economy and to identify strategic opportunities for fostering more integrated and effective CE adoption at both the firm and policy levels (Katz-Gerro & Sintas, 2018; Lopes et al., 2025; Moric et al., 2020; Tritto et al., 2023; Zamfir et al., 2017). Such an approach can reveal how knowledge and environmental spillovers, policy instruments, and organizational capabilities interact to shape the pathways and outcomes of CE adoption (Segarra-Blasco et al., 2024; Ren & Albrecht, 2023; Rizos et al., 2016). By synthesizing insights from a broad array of studies, bibliometric analysis can inform both academic research and practitioner interventions aimed at accelerating the circular transition in the SME sector.

The originality of the present study lies in addressing the above-defined gaps through both methodological and conceptual innovations. Methodologically, it applies bibliographic coupling analysis to a systematically compiled dataset of peer-reviewed publications indexed in Scopus, focusing exclusively on SMEs in the EU. This technique – unlike co-citation analysis or level-based frameworks such as MLP – identifies current intellectual linkages rather than historical citation patterns, thus capturing the most recent research connections and revealing how contemporary scholarship builds on shared theoretical foundations. The analysis combines performance metrics, scientific mapping, and keyword co-occurrence clustering to visualize the field's structure and temporal evolution, making visible the patterns that remain hidden in conventional reviews. Conceptually, this study provides the first cluster-based synthesis that explicitly maps and analyses the interconnections between four distinct yet interrelated thematic domains – environmental sustainability and performance, operational tools and implementation, business model innovation and dynamic

capabilities, and institutional and regulatory frameworks – within the European CE-SME literature. In doing so, it complements but also extends the work of Ahmadov et al. (2025) by shifting from a hierarchical, level-based lens to a relational, cross-domain mapping that explains not only *what* factors influence CE adoption but also *how* different knowledge domains interact to shape adoption pathways. This combination of methodological focus, contextual specificity, and cross-domain integration ensures the study's contribution to advancing scholarly understanding while providing a robust, evidence-based decision-support tool for policymakers, SME managers, and researchers.

The remainder of this paper is structured as follows. Section II provides a review of the literature. Section III details the methodological framework and data sources used. Section IV presents the key findings, integrating both quantitative and qualitative insights from the literature. Finally, section V discusses the broader implications of these findings and outlines an agenda for future research.

II. LITERATURE REVIEW

The circular economy (CE) has evolved from a waste management concept into a comprehensive sustainability paradigm that addresses critical issues of resource scarcity, environmental degradation, and sustainable development (Völker et al., 2020). While the term lacks universal consensus, scholars agree on its fundamental objectives: minimizing resource input and waste, maximizing material circulation, and reintegrating end-of-life products into economic systems (Suárez-Eiroa et al., 2019). This transformative approach represents a departure from the traditional linear 'take, make, dispose' model towards regenerative practices that contribute to ecological restoration rather than depletion (Reike et al., 2023).

The theoretical development of CE has been significantly influenced by key institutions, particularly the Ellen MacArthur Foundation (EMF), which has provided comprehensive frameworks articulating CE as a system-based solution for decoupling economic growth from resource consumption (EMF, 2015). The Foundation's conceptualization expanded traditional waste management perspectives into broader narratives encompassing industrial symbiosis, cross-sectoral collaboration, and cascading material flows. This institutional influence has shaped public policies, corporate strategies, and academic discourse, establishing CE as a central component of the global sustainability ecosystem. The foundational 3R principles – reduce, reuse, and recycle – have served as the starting point for operationalizing CE, particularly in waste management and sustainable consumption contexts (Hu et al., 2011; Kirchherr et al., 2017). However, scholars have increasingly argued that the 3R framework presents a relatively narrow scope for addressing CE's systemic nature (Geng et al., 2012). In response, researchers have proposed expanded frameworks, including 10Rs (Bag et al., 2021; Morseletto, 2020) and even com-

prehensive lists of 38–45 R principles (Reike et al., 2018; Mhatre et al., 2021), reflecting the increasing complexity of circular strategies and the need to differentiate between various types of resource recovery and product lifecycle extension.

The European Union has positioned itself as a global leader in promoting systemic transformation toward circularity, beginning with the first Circular Economy Action Plan (CEAP) in 2015 and reinforcing its commitment through the updated CEAP in 2020 as part of the European Green Deal.[1] The EU's approach recognizes CE's multilevel character, emphasizing cooperation across national, regional, and local levels, aligning with the macro-meso-micro framework that differentiates between national governance, industrial collaboration, and firm-level implementation (Kirchherr et al., 2017).

Despite EU-wide strategies, implementation varies significantly across Member States. While early adopters, such as Germany and the Netherlands, integrated CE principles before EU-wide strategies emerged, other countries, including Romania and Bulgaria, have only recently developed national circular economy strategies (Antikainen et al., 2018; Silvestri et al., 2020). This uneven implementation pattern creates diverse contexts for SME adoption across the European landscape (Domenech & Bahn-Walkowiak, 2019; Mazur-Wierzbicka, 2021).

SMEs play a pivotal role in CE implementation, comprising over 99% of all EU businesses and serving as key actors in operationalizing CE at the micro level.[2] Their flexibility, proximity to local markets, and capacity for innovation position them as crucial enablers of circular transformation. However, SMEs face unique challenges in CE adoption, including limited access to finance, insufficient knowledge of CE practices, and inadequate support infrastructure (Lewandowska & Stopa, 2018). Research reveals two distinct pathways for SME engagement with CE principles. Circular start-ups emerge with sustainability and eco-innovation at their core, being 'circular-by-design' with operations structured around CE principles from the outset (Cirule & Uvarova, 2022). In contrast, established SMEs face more complex transitions, often struggling with the scale and complexity of transformation due to legacy systems, sunk investments in linear business models, and internal resistance to change (Khan et al., 2022).

Empirical research identifies multiple barriers constraining SME adoption of CE practices. García-Quevedo et al. (2020) found that administrative procedure complexity and regulatory compliance costs constitute the most sig-

[1] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A new Circular Economy Action Plan for a cleaner and more competitive Europe, Brussels, 11.3.2020, COM(2020) 98 final; Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Closing the loop – An EU action plan for the Circular Economy, Brussels, 2.12.2015, COM(2015) 614 final.

[2] Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: An SME Strategy for a sustainable and digital Europe, Brussels, 10.3.2020, COM(2020) 103 final.

nificant barriers for European SMEs, while lack of human resources emerges as an additional obstacle for firms already engaged in CE activities. Financial limitations, technical expertise deficits, and the absence of supportive regulatory frameworks further constrain adoption (Rizos et al., 2016). Conversely, several enablers facilitate CE transition. Institutional pressures, including coercive, normative, and mimetic forces, drive eco-innovation and green supply-chain management, which are essential for building CE capabilities (Bag et al., 2022). Organizational factors, particularly leadership, culture, and innovation capabilities, prove critical in facilitating CE adoption, with leadership serving as a pivotal force in developing supportive cultures and innovation capabilities (Chowdhury et al., 2022).

The integration of digital technologies emerges has become increasingly important for SMEs engaged in CE initiatives. Technologies such as 3D printing and blockchain enable SMEs to exploit and adapt their CE resources effectively, providing customer value and a competitive advantage (Chaudhuri et al., 2022). Digital capabilities prove crucial for maintaining product and resource value, thereby supporting entrepreneurial sustainability (Zamfir et al., 2017). CE adoption necessitates comprehensive innovation encompassing both technological and non-technological dimensions. This transformation requires not only new recycling processes or sustainable product designs but also administrative and organizational innovations, often involving complete overhauls of supply chains, logistics, and product development cycles (de Arroyabe et al., 2021; Frishammar & Parida, 2019).

Adoption patterns and impacts vary significantly across regions and sectors. European research reveals considerable heterogeneity in CE measures, influenced by firm size, turnover, and R&D investment (Bassi & Dias, 2019). Italian SMEs employ systemic approaches that involve multiple practices, such as waste management and product design, highlighting diverse integration strategies (Mura et al., 2020). These variations underscore the need for tailored strategies to support SMEs in their circular transitions, considering specific regional contexts, sectoral characteristics, and organizational capabilities.

To sum up, CE adoption among European SMEs is a complex, multifaceted phenomenon influenced by institutional frameworks, organizational capabilities, technological enablers, and contextual factors. While significant barriers persist, emerging evidence suggests that strategic CE adoption can enhance SME performance across economic, environmental, and social dimensions, positioning circularity as both a sustainability imperative and competitive opportunity.

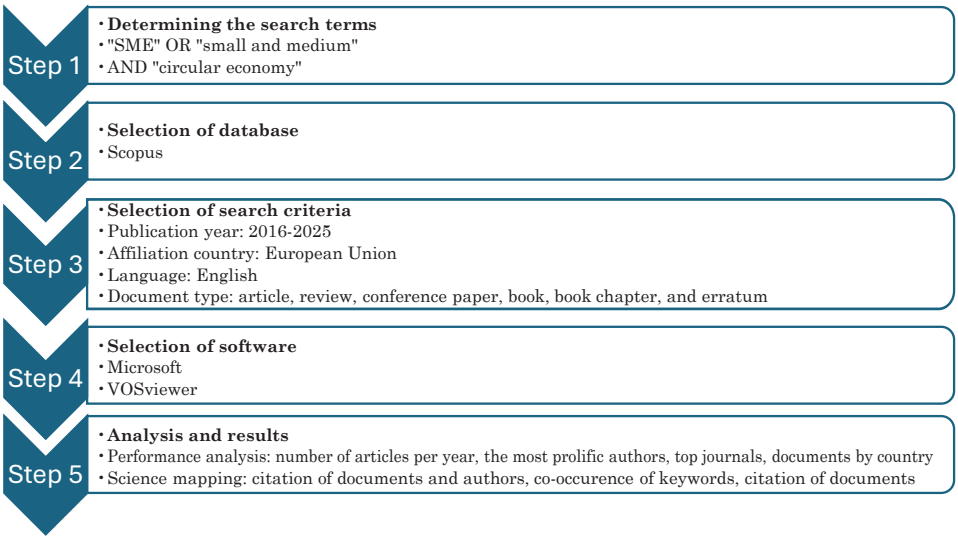
III. RESEARCH METHODOLOGY

This study employs a bibliometric approach to systematically investigate the existing literature on the circular economy within the context of EU SMEs. Bibliometric analysis is an established and rigorous method for as-

sessing scholarly output, identifying research trends, and elucidating the intellectual structure of a research domain. The study followed a structured bibliometric procedure as outlined in Figure 1.

Figure 1

Research process



Source: the authors' own study.

The literature search strategy incorporated Boolean operators – 'circular economy' AND (sme* OR "small and medium*") – applied to article titles, abstracts, and keywords. Among Scopus, Web of Science, and Dimensions, Scopus was selected as the primary data source due to its extensive coverage of peer-reviewed literature, particularly in the fields of environmental sciences, business, and management. Compared with Web of Science or Dimensions, Scopus offers broader journal inclusion in sustainability and circular economy research, along with advanced bibliometric export features that are fully compatible with tools such as VOSviewer. Furthermore, the consistency of its indexing protocols ensures a high level of data standardization, which is critical for accurate bibliometric mapping and clustering (Mongeon & Paul-Hus, 2016; Quintero-Quintero et al., 2021; Saleem et al., 2021).

English was chosen as the language criterion to ensure the inclusion of research with the broadest possible international visibility and accessibility, as English remains the dominant language of academic publishing in the CE domain. Using a common language also facilitates comparative analysis across EU countries, reducing the risk of misinterpretation arising from translation inconsistencies.

Additional filters were applied: publication year (2016–2025), affiliation country (European Union), and document type (articles, reviews, conference papers, books, book chapters, and errata). This search initially yielded 344 documents.

Bibliographic data were exported from Scopus in CSV format for subsequent analysis. Descriptive statistical analyses were conducted using Microsoft Excel to identify key trends in publications. For advanced bibliometric mapping and visualization, VOSviewer (v. 1.6.18) was employed. Its advanced clustering and network analysis functionalities facilitated the identification of thematic structures and interrelationships among publications.

Two principal bibliometric techniques were employed: performance analysis and scientific mapping. Performance analysis evaluated research productivity and impact by examining publication frequency over time, leading countries, and prominent sources of publication. Scientific mapping was used to uncover the intellectual structure of the field. This included bibliographic coupling analysis to explore connections among influential authors, and keyword co-occurrence analysis to identify prevailing research themes and emerging scholarly trends. The detailed analytical criteria – such as thresholds for keyword inclusion and minimum citation counts – are specified in the findings section to ensure methodological transparency and replicability.

IV. RESEARCH FINDINGS

The primary criterion for assessing researchers' interest in a specific scientific field and its evolving trends is the number of publications and their distribution over time. Figure 2 presents the number of publications on CE and SMEs from 2016 to the first quarter of 2025. A growing research focus is particularly evident over the past three years, coinciding with intensified discussions on the climate and energy crises, as well as the broader green transformation. As the challenges of climate change and the depletion of fossil fuel resources become increasingly urgent, the authors anticipate that this upward trend will continue in the coming years.

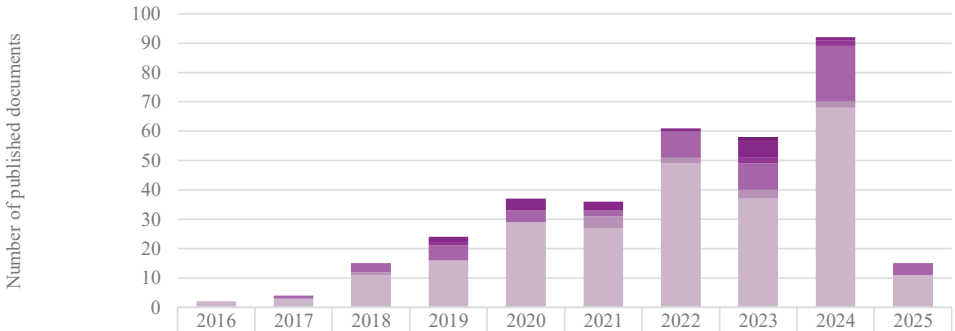
Table 1 identifies the most prolific authors in the field of CE research within the context of SMEs, defined here as scholars with a minimum of two relevant publications. The most highly cited are Bassi (University of Padova, Italy) and Dias (Instituto Universitário de Lisboa, Portugal), each with two publications and 164 citations, demonstrating a considerable degree of scholarly influence. Their research has been disseminated through *Resources, Conservation and Recycling* (IF: 10.9) – no. of citations 111 and *Business Strategy and the Environment* (IF: 13.3) – no. of citations 53, both high-impact journals in the sustainability domain.

Woodard (University of Brighton, UK) follows, with 47 citations for contributions published in *Waste Management* (IF: 7.1) – no. of citations 16 and the

Journal of Cleaner Production (IF: 10.0) – no. of citations 31. Kiefer, del Río, and Carrillo-Hermosilla (CSIC and Universidad de Alcalá, Spain) have collectively accrued 42 citations from works published in *Resources, Conservation and Recycling* (IF: 10.9) – no. of citations 39 and *Corporate Social Responsibility and Environmental Management* (IF: 9.1) – no. of citations 3. Brendzel-Skowera (Czestochowa University of Technology, Poland) ranks next with 41 citations from publications in *the Proceedings of the 33rd International Business Information Management Association Conference* and *Sustainability* – no. of citations 2 and Sustainability (IF: 3.3) – no. of citations 39. Ramos and Martinho (NOVA University of Lisbon, Portugal) have 39 citations, with articles in *Waste Management* (IF: 7.1) – no. of citations 24 and the *Journal of Building Engineering* (IF: 7.4) – no. of citations 15.

Figure 2

Number of published documents on the circular economy and SMEs in the period 2016–2025



	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025
Erratum								1		
Book chapter				2	4	3	1	6	1	
Book				1				2	2	
Conference paper		1	3	5	4	2	9	9	19	4
Review			1			4	2	3	2	
Article	2	3	11	16	29	27	49	37	68	11

Source: the authors' own study based on the Scopus database.

Although citation counts exhibit marked variation, the distribution of contributions across multiple high-impact journals and the prevalence of collaborative, multi-institutional authorship suggest a progressively expanding – albeit geographically and thematically uneven – academic engagement with CE adoption in SMEs.

The most popular and valuable journals in the field of the circular economy and SMEs are *Business Strategy and the Environment* (Wiley Online Library, IF: 13.3) with 2014 citations and 32 publications, *Journal of Cleaner Production* (Elsevier, IF: 9.8) with 1754 citations and 23 published articles, and *Sustainability* (MDPI, IF: 3.3) with 1583 citations and 35 publications.

They are followed by the *Journal of Business Research* (Elsevier, IF: 10.5) with 984 citations and 16 articles, and the *Resources, Conservation and Recycling* (Elsevier, IF: 11.2) with 486 citations and 9 papers.

Table 1

The leading authors of documents on the circular economy and SMEs

Authors	No. of citations	No. of papers	Journal
Bassi, Francesca and Dias, José G.	164	2	Resources, Conservation and Recycling (IF: 10.9) Business Strategy and the Environment (IF: 13.3)
Woodard, Ryan	47	2	Waste Management (IF: 7.1) Journal of Cleaner Production (IF: 10.0)
Kiefer, Christoph P.; Carrillo-Hermosilla, Javier; del Río, Pablo	42	2	Resources, Conservation and Recycling (IF: 10.9) Corporate Social Responsibility and Environmental Management (IF: 9.1)
Brendzel-Skowera, Katarzyna	41	2	Proceedings of the 33rd IBIMA Conference Sustainability (IF: 3.3)
Ramos, Mário; Martinho, Graça	39	2	Waste Management (IF: 7.1) Journal of Building Engineering (IF: 7.4)

Source: the authors' own study based on the Scopus database.

The key subjects of the research are publications by country, including their social networks (Peng et al., 2020). Table 2 presents the most important countries according to citation counts and the number of published papers on the SME circular economy practices. Within this EU-focused dataset, the United Kingdom leads with 4064 citations and 84 papers (23.84%), Spain with 2265 citations and 39 papers (11.34%), and Italy with 2143 citations and 84 papers (24.42%) representing more than half of all EU circular economy and SME research. Citation impact disparities within the EU context highlight qualitative differences in research approaches. Spain demonstrates exceptional research impact (58.1 citations per paper) compared to Italy's lower ratio (25.5 citations per paper), suggesting superior international visibility despite both countries' EU membership. Poland's weak citation performance (13.8 citations per paper) indicates potential language barriers or methodological limitations affecting broader EU academic influence. Regional EU clustering emerges clearly, with Southern European countries (Spain: 39 papers, Portugal: 30 papers) forming a distinct research network, while Nordic EU members (Sweden: 17 papers, Finland: 13 papers, Denmark: 12 papers) demonstrate collaborative sustainability research traditions. France and Germany's moderate contributions (22 and 21 papers respectively) appear surprisingly limited given their economic significance within the EU.

Table 2

Documents on circular economy and SME by country

Country	No. of citations	No. of papers	% of 344
United Kingdom	4064	82	23.84
Spain	2265	39	11.34
Italy	2143	84	24.42
India	1570	26	7.56
Greece	1488	16	4.65
Germany	1203	21	6.10
Netherlands	980	10	2.91
France	965	22	6.40
Portugal	951	30	8.72
Belgium	853	5	1.45
China	552	12	3.49
Austria	522	8	2.33
Sweden	506	17	4.94
Finland	485	13	3.78
Denmark	467	12	3.49

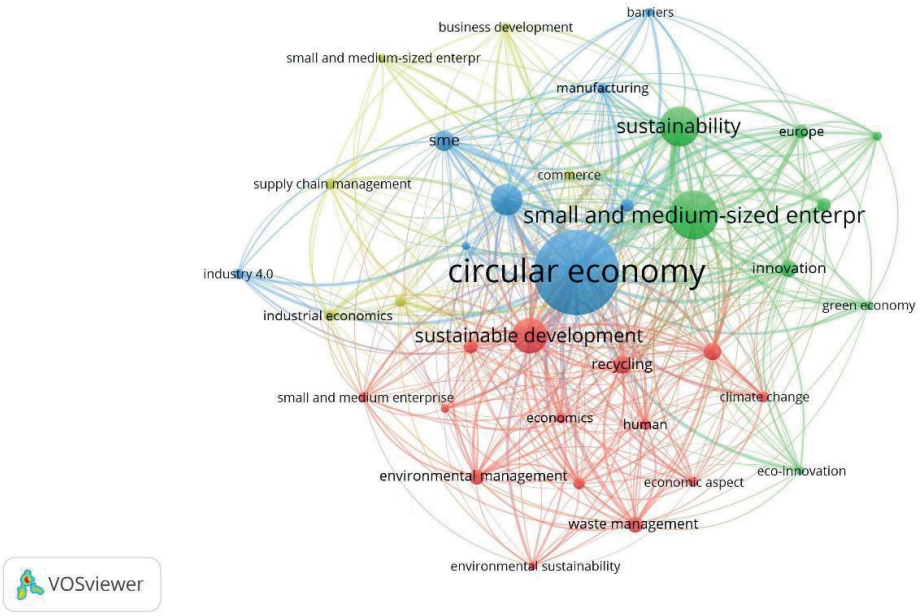
Source: the authors' own study based on the Scopus database.

Figure 3 shows a co-occurrence map of authors' keywords (fractional counting), where colours distinguish clusters and interconnected keywords indicate frequent co-occurrence. Circle size reflects keyword frequency, and line thickness represents the strength of associations. This visualization highlights relationships between key concepts and offers insights into the evolving research landscape. The analysis identifies four thematic clusters, each with a distinct conceptual focus yet interconnected within the broader research domain. To be included, a keyword needed at least 10 occurrences, reducing the set from 2,247 to 40. Four irrelevant terms (e.g. article, literature review) were excluded. The resulting network captures the multifaceted nature of the research problem and the conceptual diversity shaping the field.

Cluster 1 (Red) emerges as the largest cluster, with 14 keywords, emphasizing the environmental dimensions of circular economy implementation. This cluster centres on fundamental concepts, including climate change, environmental impact, and environmental sustainability, reflecting the ecological motivations driving circular economy adoption. The prominence of keywords such as 'environmental economics,' 'environmental management,' and 'waste management' indicates a strong focus on quantifying and managing environmental consequences. The inclusion of 'sustainable development' and 'recycling' suggests this cluster addresses the operational aspects of environmental stewardship in business contexts.

Figure 3

Co-occurrence map of authors' keywords



Source: the authors' own study based on the Scopus database.

Cluster 2 (Green) comprises 8 keywords focused on the technological and industrial aspects of circular economy implementation. The central positioning of 'circular economy' within this cluster, alongside 'industry 4.0' and 'manufacturing,' highlights the integration of digital technologies with circular business models. Keywords such as 'business models' and 'barriers' indicate research attention toward identifying implementation challenges and developing innovative solutions. The cluster's focus on industrial economics and SME-specific considerations reflects recognition of scale-specific implementation challenges and opportunities.

Cluster 3 (Blue) comprises 8 keywords that address the macroeconomic and policy dimensions of circular economy transitions. The cluster's emphasis on 'green economy,' 'innovation,' and 'economic conditions' suggests a research focus on broader systemic factors that enable circular economy development. The inclusion of 'Europe' indicates geographical concentration of research, possibly reflecting regional policy initiatives and regulatory frameworks.

Cluster 4 (Yellow) represents the smallest cluster, comprising 6 keywords, and focuses on practical implementation aspects within organizations. The emphasis on 'business development,' 'commerce,' and 'supply chain manage-

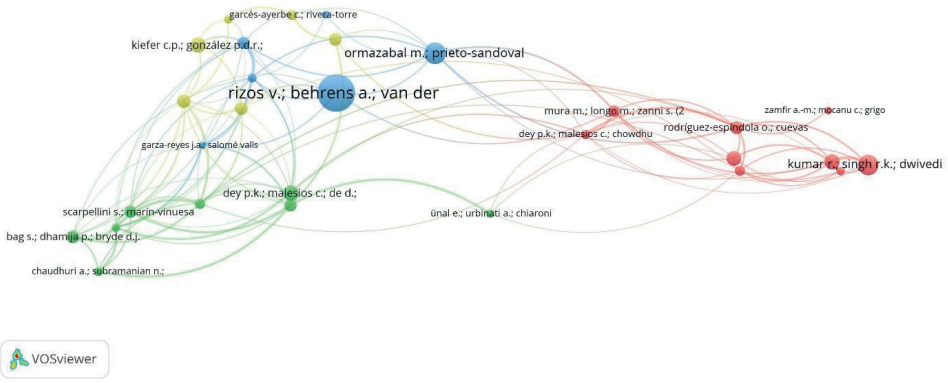
ment' indicates a focus on operational efficiency and value creation through circular practices.

The interconnected nature of these clusters, evident from the network visualization, demonstrates the holistic approach required for successful circular economy implementation in SMEs. The strong connections between environmental sustainability (Cluster 1) and business innovation (Cluster 2) underscore the need to align ecological objectives with technological advancements. Similarly, the linkages between economic systems (Cluster 3) and operational management (Cluster 4) emphasize the importance of supportive policy environments for effective implementation. This clustering pattern reveals circular economy research in SMEs as an interdisciplinary field requiring integration with environmental science, business strategy, technology management, and policy analysis for a comprehensive understanding and successful implementation.

The bibliographic coupling analysis reveals a sophisticated intellectual structure within circular economy and SME research, demonstrating how scholarly knowledge is interconnected through shared reference patterns. This analysis examines 29 high-impact publications (≥ 100 citations) from the initial corpus of 344 papers, providing crucial insights into the theoretical foundations and methodological approaches that define this research domain. The visual representation reveals four distinct clusters, each signifying a cohesive thematic grouping within the research landscape, illustrating varying degrees of interconnectedness and relationship strength among documents that have significantly influenced the field's development (Figure 4).

Figure 4

The bibliographic coupling analysis



Source: the authors' own study based on the Scopus database.

The emergence of four distinct clusters through bibliographic coupling indicates the presence of specialized research streams, each characterized by unique theoretical perspectives and methodological approaches. Unlike co-

citation analysis, which examines forward citations, bibliographic coupling examines backwards citations, revealing how contemporary research builds upon established theoretical foundations. This approach illuminates the intellectual scaffolding supporting current research trajectories and identifies the seminal works that continue to influence scholarly discourse.

The Red Cluster (9 papers) focuses on environmental sustainability outcomes and performance measurement frameworks, rooted in environmental economics and sustainability assessment theories. It explores how CE principles drive measurable environmental benefits and organizational improvements. Dey et al. (2022) present evidence from France, Greece, Spain, and the UK, demonstrating that CE adoption enhances environmental performance through improved energy and resource efficiency, highlighting the 'design' function as most influential, while 'recover' is the least implemented. Mura et al. (2020), analysing 254 Italian SMEs, find systemic value creation essential, with waste management widely used, yet resource-saving practices underutilized. Rodríguez-Espíndola et al. (2022) expand the geographic scope to Mexican SMEs, showing CE-driven sustainability innovation improves financial, environmental, and social outcomes. D'Amato, Veijonaho, & Toppinen (2020) provide a sectoral lens via Finnish forest-based SMEs. Centobelli et al. (2021) confirm the impact of environmental commitment and green incentives on sustainable design and supply chain management. Foundational insights come from Zamfir et al. (2017) using Flash Eurobarometer data to map CE adoption. Birkel & Müller (2021) integrate Industry 4.0 perspectives, while Lu et al. (2020) and Kumar et al. (2020) link technological challenges to ethical, sustainable operations.

The Blue Cluster (6 papers) is the most practically oriented, as it is anchored in implementation science and operational management theory. It focuses on measurement tools, barriers, enablers, and strategic solutions. Garza-Reyes et al. (2019) address the measurement gap via the Circularity Measurement Toolkit (CMT). Prieto-Sandoval et al. (2018) identify three core assessment elements: circular activity scope, industrial symbiosis, and environmental certification. Rizos et al. (2016) highlight financial and knowledge barriers despite CE's cost-saving and market potential. Ormazabal et al. (2018) find Spanish SMEs often remain in reactive compliance. Bassi and Dias (2019) provide a European comparative perspective on disparities in CE uptake. Prieto-Sandoval et al. (2019) recommend eco-innovation, investment in circular business models, and developing strategic capabilities that align sustainability with economic performance.

The Green Cluster (8 papers) draws on innovation theory and strategic management, exploring business model innovation and dynamic capabilities. Chaudhuri, Subramanian, & Dora (2022) demonstrate how recycling SMEs

leverage adaptive and exploitative capabilities through digital technologies. Bag et al. (2022) show that institutional pressures foster eco-innovation and strengthen CE capabilities in South African SMEs. Chowdhury et al. (2022) highlight leadership and culture in building CE capabilities in Vietnam. Scarpellini et al. (2020) apply dynamic capabilities theory to Spanish firms. Sharma et al. (2021) identify 3R principles, awareness, and funding as key barriers. Dey et al. (2020) develop a CE framework for UK SMEs. Ünal, Urbinati, & Chiaroni (2019) and Ünal et al. (2019) offer case studies illustrating value creation in CE business models in Italy and the USA.

The Yellow Cluster (6 papers) is grounded in institutional theory and regulatory economics, focusing on policy and governance frameworks shaping CE adoption. García-Quevedo et al. (2020) identify regulatory complexity and compliance costs as key barriers. Demirel & Danisman (2019) show threshold investments are needed for SMEs to benefit from CE. Kiefer et al. (2019) analyse resources and competences as determinants of eco-innovation. Katz-Gerro & López Sintas (2019) map CE activity patterns in EU SMEs. Garcés-Ayerbe et al. (2019) and Awan & Sroufe (2022) provide implementation perspectives and conceptual success factor models.

While these clusters originate from distinct theoretical traditions – environmental economics (Red), operational management (Blue), innovation theory (Green), and institutional theory (Yellow) – recent scholarship shows increasing thematic convergence:

– Red and Blue – Linking performance outcomes with practical measurement tools.

– Blue and Green – Combining operational frameworks with innovation capabilities.

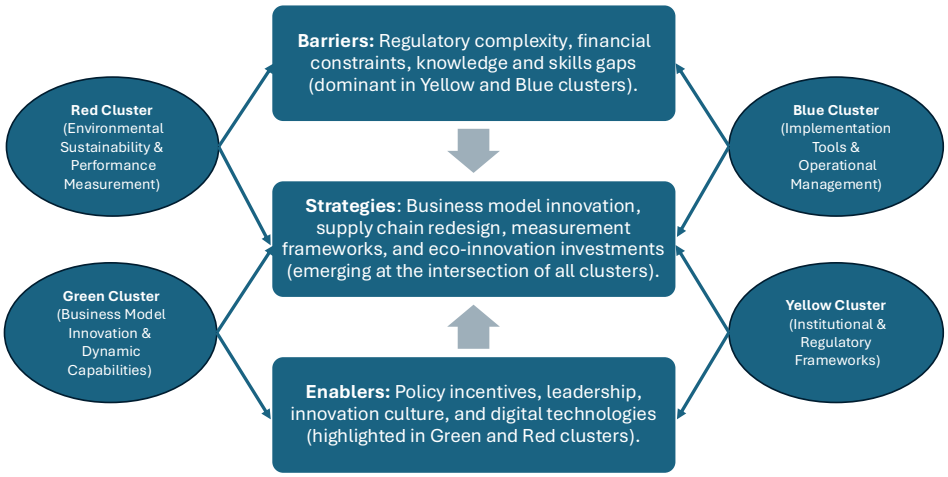
– Green and Yellow – Aligning business models with institutional and policy frameworks.

Early works (pre-2020) tended to address these dimensions separately, whereas more recent studies adopt integrated, interdisciplinary perspectives. This evolution reflects a maturation of the field from fragmented thematic silos toward holistic frameworks that interlink barriers, enablers, and strategic responses.

To capture these interconnections, Figure 5 proposes a CE Adoption Integration Framework linking the four bibliometric clusters to the main barriers, enabling factors, and strategic responses identified in the literature. This model emphasizes that CE adoption in SMEs is a systemic transformation requiring alignment between environmental goals, organizational innovation, operational tools, and supportive policy environments. By situating each cluster within this system, the framework serves both as a theoretical map of the intellectual structure and a practical guide for targeted interventions.

Figure 5

Conceptual synthesis of bibliometric clusters concerning barriers, enablers, and strategies for CE adoption in SMEs



Source: the authors' own study based on the Scopus database.

V. DISCUSSION

This bibliometric study confirms a growing academic focus on the adoption of the circular economy (CE) among SMEs in the EU, particularly since 2020. This surge reflects broader socio-political trends such as the European Green Deal, climate challenges, and the dual push for digital and sustainable transformation. The increase in publication volume and the emergence of four thematic clusters – strategic barriers and opportunities, digital enablers and organizational readiness, measurement and operational challenges, and economic drivers and policy impacts – demonstrate the complex and interconnected nature of CE adoption in SMEs.

The identified clusters align closely with findings from the literature review. Cluster 1 (environmental sustainability and impact assessment) confirms that CE adoption can enhance environmental performance, particularly in terms of energy efficiency and waste reduction (Dey et al., 2022; Mura et al., 2020). However, implementation varies across EU countries due to differing levels of regulatory and institutional support (Bassi & Dias, 2019; Katz-Gerro & Sintas, 2018). Cluster 2 (business innovation and industrial transformation) emphasizes the role of Industry 4.0 tools – such as blockchain and 3D printing – as key CE enablers (Chaudhuri et al., 2022). Yet, technology must be coupled with leadership and an innovation culture (Chowdhury et al., 2022). Cluster 3 (economic systems and policy frameworks) underscores the influence of macroeconomic conditions and institutional pressures – coercive, normative, and mimetic – on eco-innovation and green supply-chain practices

(Bag et al., 2022). However, many SMEs still face financial, administrative, and knowledge-related barriers (García-Quevedo et al., 2020; Rizos et al., 2016), which highlights the gap between policy ambitions and the capacities of SMEs. Cluster 4 (operational management and performance) focuses on firm-level practices. While recycling and waste minimization are widespread, more advanced CE strategies – such as product redesign and resource recovery – are less common (Ormazabal et al., 2018; Prieto-Sandoval et al., 2019). There remains a strong need for better performance measurement and managerial capabilities to guide CE transitions.

The interconnectedness of the clusters, visible in bibliometric visualizations, confirms the need for a holistic CE approach. Bag et al. (2022) emphasize this integration in their study on institutional drivers of green supply chains. Additionally, the geographical analysis reveals uneven research and CE adoption across Europe, with Western and Southern Europe leading, reflecting broader disparities in CE policy implementation and innovation ecosystems (Domenech & Bahn-Walkowiak, 2019). In sum, effective CE adoption in SMEs requires integrated leadership, technology, policy support, and performance tracking.

1. Future research directions

The interconnected nature of the identified clusters suggests that future high-impact research should emphasize integrated approaches combining environmental, strategic, operational, and institutional perspectives. The analysis reveals gaps in understanding cross-sectoral digital adoption and the need for unified CE measurement frameworks that consider both economic and operational aspects. This aligns with the emphasis in the literature review on digital technologies becoming increasingly important for SMEs engaged in CE initiatives, where technologies such as 3D printing and blockchain enable effective resource utilization and competitive advantage creation (Chaudhuri et al., 2022). Future research should address the measurement gap identified by Garza-Reyes et al. (2019) by developing comprehensive assessment tools that integrate the three essential elements proposed by Prieto-Sandoval et al. (2018): circular activity scope, industrial symbiosis role, and the importance of environmental certification. The bibliographic coupling analysis suggests that combining insights from the Blue Cluster's measurement frameworks with the Green Cluster's business model innovation perspectives could yield more robust evaluation methodologies.

2. Theoretical implications

This bibliometric analysis makes key theoretical contributions to the circular economy (CE) and SME literature, advancing management and quality sciences. It offers empirical evidence of the multidimensional nature of CE adoption, identifying four interconnected thematic domains – environmental sustainability and performance (Red Cluster), implementation and operation-

al management (Blue Cluster), business model innovation and dynamic capabilities (Green Cluster), and institutional and regulatory frameworks (Yellow Cluster). This integration shows CE adoption to be an environmental, operational, strategic, and institutional phenomenon, reinforcing systems thinking in management science.

Using bibliographic coupling, the study advances institutional theory with cross-country EU evidence by showing that coercive pressures (e.g. compliance costs), normative pressures (e.g. sectoral norms), and mimetic pressures (e.g. leader-driven adoption) have varying impacts. In stable policy contexts with targeted incentives, SMEs integrate CE into business models (Green Cluster), while weaker frameworks restrict adoption to recycling or compliance (Blue Cluster).

Finally, the analysis enriches innovation theory by showing the dual nature of CE-related innovation. Alongside technological advances – such as Industry 4.0 tools for resource optimization – non-technological innovations (e.g., governance models, collaborative supply chains, eco-certifications) are equally decisive. This extends the Schumpeterian perspective, embedding administrative and organizational innovation into the conceptualization of CE capabilities.

3. Practical implications

The findings of this study provide actionable guidance for policymakers, SME managers, and researchers promoting circular economy (CE) adoption in Europe. For policymakers, the bibliometric mapping of four thematic clusters offers a diagnostic tool for targeted interventions. In contexts where regulatory complexity is a major barrier (Yellow Cluster), simplifying administrative procedures and creating one-stop advisory platforms can support SMEs through the transition. Where financial constraints limit adoption (Blue Cluster), tailored instruments – such as micro-grants or low-interest loans – can fund eco-innovation and digitalization. Geographical patterns also enable benchmarking against EU frontrunners, adopting best practices such as cross-border knowledge-sharing seen in Southern Europe's collaborative sustainability networks.

For SME owners and managers, the cluster analysis provides a strategic roadmap linking environmental objectives, operational practices, and business model innovation. The Red Cluster encourages integrating measurable indicators – for example resource efficiency ratios, carbon intensity – into performance dashboards to monitor progress and communicate value. The Blue Cluster highlights structured assessment tools, such as the Circularity Measurement Toolkit (Garza-Reyes et al., 2019), for evaluating CE maturity. The Green Cluster emphasizes combining digital investments (e.g. blockchain for supply chain transparency, 3D printing for material efficiency) with leadership development to embed innovation. The Yellow Cluster underlines proactive engagement with regulators and industry associations to anticipate compliance changes and leverage support.

For researchers and consultants, the results offer a validated framework for assessing CE readiness and impact. The dataset supports comparative studies on sector-specific adoption patterns and serves as a coding framework for qualitative research or a foundation for CE maturity models integrating environmental, operational, strategic, and institutional dimensions. In consultancy, these findings can guide tailored CE transition pathways, using bibliometric evidence to prioritize actions and justify resource allocation.

VI. CONCLUSIONS

This study analysed the scale, dynamics, and thematic trends in Circular Economy (CE) research among SMEs in the European Union, based on 344 Scopus-indexed publications (2016–2025). It mapped influential contributions, identified four thematic clusters (environmental sustainability and impact assessment, business innovation and industrial transformation, economic systems and policy frameworks, and operational management and performance) and explored the interconnections between CE barriers, enablers, and eco-innovation strategies. Bibliographic coupling of 29 high-impact publications revealed strong intellectual links, indicating a shift in the field towards integrated, interdisciplinary approaches. The clusters demonstrate that effective CE adoption in SMEs requires a holistic strategy that aligns environmental goals with technological innovation and supportive policy frameworks.

However, limitations must be acknowledged. Excluding non-English publications may result in the underrepresentation of research conducted in national languages, particularly from countries where CE research is developing but is less frequently published internationally. Similarly, reliance on a single database means that relevant studies indexed exclusively in other repositories (e.g. national databases, Web of Science) were not captured. Consequently, while the findings provide a robust overview of internationally visible CE research in SMEs, they may not fully reflect local or emerging scholarly contributions. The emphasis on EU-affiliated studies, while offering regional depth, may reduce applicability to other global contexts. Moreover, the bibliometric approach prioritizes quantitative outputs, limiting in-depth qualitative assessment of theoretical and methodological advances. Despite these constraints, the study offers a valuable overview of the CE research landscape among EU SMEs. It establishes a solid foundation for future investigations into region-specific strategies, cross-sectoral dynamics, and emerging practices that are currently underrepresented in the literature.

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50% (Conceptualization / Konceptualizacja; Data curation / Zarządzanie danymi; Formal analysis / Formalna analiza; Investigation / Przeprowadzenie badań; Methodology / Metodologia; Validation / Walidacja; Visualization / Wizualizacja; Writing – original draft / Pisanie – pierwszy szkic; Writing – review & editing / Pisanie – recenzja i edycja).

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