



## Research article

# Navigating climate pressures: A bibliometric and systematic literature review of climate change strategies in small and medium-sized enterprises

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## ARTICLE INFO

## Keywords:

Climate change  
Extreme weather events  
Business strategies  
Business responses  
Small and medium sized enterprises

## ABSTRACT

Climate change poses increasingly complex business challenges, particularly in navigating survival and growth in uncertain environments. While substantial research has investigated the relationship between climate change and large organizations, the strategic responses of Small and Medium-Sized Enterprises (SMEs) remain underexplored. This study addresses this gap by examining the evolution of scholarly literature on climate-related strategies in SMEs, identifying key trends, and outlining future research directions. Through a systematic literature review of 91 articles from the Web of Science database, we applied bibliometric techniques, including co-citation and bibliographic coupling analyses, paired with a thematic cluster analysis to uncover the new trends in the field. Our findings reveal that this domain entered a "Development Phase" in 2020, with contributions predominantly concentrated in Europe and Asia, highlighting significant regional disparities in research focus and contexts. Six thematic clusters from bibliographic coupling and three from co-citation analysis illustrate the diverse yet fragmented foundations of the field. We emphasize the need to expand the geographic and institutional diversity of the field by proposing targeted avenues for future research that consider the institutional, cultural, and sectoral contexts shaping SMEs' climate-related strategies. By advancing theoretical frameworks and policy-relevant insights, we aim to inform effective interventions for mitigating climate challenges globally.

## 1. Introduction

Climate change, marked by rising global temperatures, altered precipitation patterns, and an increasing frequency of extreme weather events, presents escalating challenges for businesses worldwide [1,2]. In this regard, Small and Medium-Sized Enterprises (SMEs) are particularly vulnerable [3]. Representing approximately 95 percent of all businesses in industrialized economies, SMEs are

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<https://doi.org/10.1016/j.heliyon.2025.e43610>

Received 25 October 2024; Received in revised form 6 June 2025; Accepted 4 July 2025

Available online 10 July 2025

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pivotal contributors to Gross Domestic Product and employment [4]. Yet their significance extends beyond these metrics: SMEs' cumulative energy consumption, dependence on natural resources, and susceptibility to climate-induced disruptions make them critical players in addressing environmental challenges [1,5–7]. Rising production costs, supply chain disruptions, infrastructural vulnerabilities, and heightened exposure to environmental changes further underscore the urgency for SMEs to adopt effective strategies to address the challenges posed by climate change [8–10].

Despite their critical role, scholarly attention on SMEs' climate-related strategies remains fragmented, underexplored, and undertheorized [1,2,11–13]. Most economy and management research has focused on large enterprises, which typically possess greater resources and capabilities to address climate challenges [14]. In contrast, SMEs often struggle with resource limitations, including insufficient liquidity, a shortage of skilled labor, and weak managerial capacity to respond to and adapt to climate change [13,15–17]. Moreover, although SMEs face these global challenges, their critical role as key actors in energy transition and decarbonization policies—across both low- and middle-income economies as well as high-income economies—has been largely overlooked [4,8,18]. Addressing this gap, existing research [6,15,16,19–23] has examined SMEs' climate-related behaviors, strategies, and environmental outcomes. However, our understanding of how SMEs can effectively confront these external challenges remains limited, hampering the development of tailored policies and tools that address the unique features of SMEs. Without such insights, policy-makers and business leaders are ill-equipped to promote sustainable practices and climate resilience within this vital business community.

The dual role of SMEs—as both contributors to and a business community affected by climate change—underscores the urgent need for focused research [24]. Indeed, SMEs play a pivotal role in steering global economic activity toward a resource-efficient, low-carbon economy [24], as they can influence other stakeholders, including suppliers, customers, and organizations, toward sustainable economic practices [25]. Addressing these challenges, however, requires a nuanced understanding of how SMEs perceive, develop, and implement strategies to navigate environmental pressures [13]. Gaining insights into these processes is crucial for designing effective interventions that enhance SMEs' sustainability, resilience, and adaptive capacity. Therefore, this study systematically reviews the evolution of the literature on SMEs and climate change, focusing on two research questions: How has the literature on SMEs and climate-related strategies evolved? And what are the emerging research directions within this field? By synthesizing the existing body of knowledge on this topic, we address the Sustainable Development Goals (SDGs), particularly SDG 12 (responsible consumption and production) and SDG 13 (climate action), by highlighting the strategic responses of SMEs to climate change. Second, we underscore the importance of regionally informed policies and targeted research to support SMEs in adopting climate-related business strategies. Finally, we bridge critical knowledge gaps, offering actionable insights for researchers, policymakers, and business leaders aiming to foster climate resilience and sustainability within this sector.

The remainder of this article is structured as follows: Section 2 describes the data and methodology used for the systematic review. Section 3 presents the results, organized into two subsections based on the scope of the analysis. Section 4 discusses the implications of our findings, highlights empirical gaps, and suggests future research directions. Finally, Section 5 concludes by summarizing the key insights of this study and addressing its limitations.

## 2. Material and methods

We employed a four-stage Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) protocol [1,26], ensuring a transparent and systematic approach to reviewing the literature. Fig. 1 illustrates the procedures, descriptions, and criteria applied at each stage: Identification, Screening, Eligibility, and Inclusion. To enhance the depth and rigor of our analysis, we

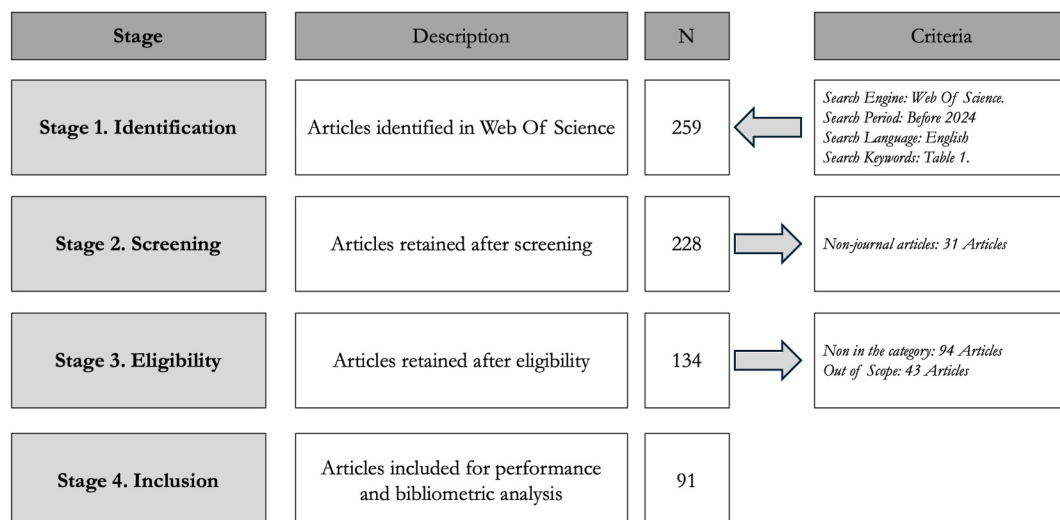


Fig. 1. PRISMA protocol.

incorporated the Bibliometric-Systematic Literature Review (B-SLR) framework, which provides structured guidelines for synthesizing literature and supporting theory development through the critical evaluation of existing research [27]. The B-SLR follows a 10-step process, offering researchers critical decision points and best practices at each stage of the review, thereby facilitating the creation of comprehensive, meaningful, and theoretically grounded literature reviews.

## 2.1. Stage 1- identification

The identification stage aimed to gather suitable material for analysis through a systematic search conducted in the Web of Science (WOS) database [28] on March 15, 2024. This methodological choice was made considering WOS's reputation as a high-quality source [29] (pp. 1812) for management [30] (pp. 1022), and economic research [31] (pp. 1242) in comparison to other databases, taking into account language coverage [32] (pp. 214), citation count [33] (pp. 614), and publication metadata [34] (pp. 5). Moreover, WOS has been recognized as an authoritative index worldwide, ensuring that the research included is representative and credible [35]. While WOS served as the primary database for this study, cross-validation was conducted with Scopus to identify any potential missing materials. The preliminary comparison (available as supplementary material), which applied identical inclusion-exclusion criteria (detailed in the subsequent subsections), revealed that Scopus yielded a narrower range of relevant articles. This further justified the selection of WOS for the subsequent stages due to its more comprehensive coverage.

To minimize researcher bias [1] (pp. 5), our research protocol was peer-reviewed by a climate-change expert, who evaluated the keywords, assessed the inclusion-exclusion criteria, and provided feedback on the preliminary set of papers we identified. Overall, this protocol aimed to capture all relevant research material on WOS up to 2023, the last complete year of publications available at the time of data collection. Our search strategy utilized a Boolean sequence targeting key terms (see Table 1) within the title, abstract, or keywords. Specifically, a previous thesaurus of keywords related to climate change (e.g., "climat chang\*", "global warm\*", "carbon emission\*") [1], SMEs (e.g., "SME," "small business\*," "medium enterprise") [36], and climate-related strategies [2] (e.g., "strategy\*," "mitigation\*," "resilience\*") was employed. This approach ensured a comprehensive and systematic identification of relevant literature. A total of 259 articles were identified as relevant for subsequent analysis.

## 2.2. Stage 2- screening

Subsequently, in stage 2, we applied a set of inclusion criteria to identify relevant papers for in-depth analysis. The initial criteria focused on peer-reviewed journal articles, excluding other academic materials such as books, book chapters, industry reports, and conference proceedings that were not peer-reviewed [1]. As a result, 31 documents that did not meet this criterion were excluded. Afterward, the second criterion aimed to identify peer-reviewed articles within specific academic categories that facilitate a multi-disciplinary exploration of the phenomenon of interest [1]. The inclusion criteria encompassed 11 categories: Environmental Sciences, Environmental Studies, Green Sustainable Science and Technology, Management, Business, Environmental Engineering, Development Studies, Economics, Hospitality, Leisure, Sport and Tourism, Multidisciplinary Sciences, Business Finance, and Operations Research and Management Science. Consequently, 94 articles that fell outside these categories were excluded. After the screening stage, 134 documents were identified as relevant for in-depth analysis and advanced to the next stage.

## 2.3. Stage 3- Eligibility

In stage 3, the research team conducted an in-depth analysis of the remaining documents to ensure their content, rather than the mere presence of keywords, aligned with the phenomenon of interest. This process involved a thorough review of the titles and abstracts of all articles. Articles were excluded based on the following criteria:

**Exclusion Criterion 1:** The document contained the key terms, but its core focus of analysis differed from assessing the climate-related strategies of SMEs. A total of 30 articles were excluded, including references such as [37].

**Exclusion Criterion 2:** The document was a systematic review with a different focus from the core phenomenon of interest. A total of seven articles were excluded, including references such as [38].

**Exclusion Criterion 3:** The document did not focus on the firm level but explored climate-related strategies at the household, industrial, regional, or national levels. A total of six articles were excluded, including references such as [39].

The climate-change expert validated all included and excluded documents and confirmed the final selection of the remaining sample. Through this process, 91 articles met all the criteria and advanced to the inclusion stage. For the selected 91 articles, all

**Table 1**  
Research keywords.

| Theme          | Keywords                                                                                                                                                                                                                                                                                                                                 | Reference |
|----------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------|
| SME            | ("SME" OR "small firm*" OR "small business*" OR "medium firm*" OR "medium business*" OR "small enterprise" OR "medium enterprise" OR "small- to medium-sized enterprise" OR "small-sized* enterprise*" OR "medium-sized* enterprise*" OR "small- and medium-sized enterprises*")                                                         | [36]      |
| Strategy       | ("practices*" OR "strategy*" OR "strategic*" OR "mitigation*" OR "adaptation*" OR "resilience*")                                                                                                                                                                                                                                         | [2]       |
| Climate Change | (climat* chang*" OR "climat* warming*" OR "global temperature*" OR "global warm*" OR "greenhouse gas*" OR "greenhouse effect*" OR "greenhouse warm*" OR "anthropogenic warming*" OR "anthropogenic emission*" OR "climat* model*" OR "environment* chang*" OR "global chang*" OR "climat* variability and change" OR "carbon emission*") | [1]       |

bibliometric information, including references and citation counts, was retrieved for further analysis. The supplementary material provides access to our final sample of articles employed in this study.

## 2.4. Stage 4- inclusion

Stage 4 involved initial validation of the entire research protocol by the research team to ensure the robustness of the overall process, as suggested by previous bibliometric research [27]. This validation process included a thorough review of stages 1 through 3 by the team and a final confirmation from the external expert before proceeding with the subsequent in-depth analysis. Following this, we conducted both bibliometric and thematic analyses of literature. The bibliometric analysis consisted of two parts [1,40]: first, a performance analysis that statistically described the evolution of this research topic. Specifically, we examined overall publication trends and analyzed contributions by world regions, journals, institutions, authors, and articles, using citation count measures. Moreover, we described the main research trends based on the content of the articles, including core theoretical frameworks employed, economic sector coverage, and the predominant types of research approaches. The selection of these measures was made in line with standard practices in bibliometric research [40].

Next, we employed two complementary science mapping techniques—citation-based information networks [40,41]: document co-citation networks and bibliographic coupling. A document co-citation network captures the patterns that emerge when two references are cited together by other articles [42], helping us identify seminal theoretical works and key empirical studies that form the foundation of the literature [40]. In contrast, a bibliographic coupling network [42,43] examines the connections between articles that share common references, revealing research hotspots and emerging trends within the field [40]. We utilized VOSviewer software (Version 1.6.20) [44], which enables the mapping and analysis of bibliometric networks. The software visualizes these similarities using the VOS (Visualization of Similarities) method (see Ref. [45] for a full description of the method), which is based on similarity measures, specifically association strength, between nodes in the network [46]. VOS aims to minimize the weighted sum of the squared Euclidean distance between pairs of nodes [46] resulting in a two-dimensional map that positions the nodes in the network such that the distance between each pair reflects their level of similarity [45]. For network mapping, we applied a normalization method based on association strength, in line with the VOS method, setting clusters with a minimum size of 1.0 and a resolution of 1.0. This approach allowed us to visualize and identify distinct communities within the network. Based on these identified network communities, we conducted a thematic analysis, examining the commonalities within each cluster. Each cluster was assigned a label, and the core insights relevant to our research question were described. Finally, we conducted an in-depth analysis of the clustered articles to propose an agenda for future research. We note that the data supporting this research are available in the Supplementary Material. Ethics committee approval was not required for this study, as it utilized documentary information collected from publicly accessible databases.

## 3. Results

### 3.1. Performance analysis

#### 3.1.1. Publication trends

Fig. 2 illustrates the publication trends in this topic, revealing three distinct phases in the literature. The first phase, labeled the "Introduction Phase," spans between 2008 and 2015. This period is characterized by limited scholarly output, with only 10 articles published and an annual average of 1.7 articles. The second phase, labeled as the "Growth Phase," covers the period between 2016 and 2019. During this time, there was a significant increase in publications, with a growth rate of 99.3 percent compared to the previous

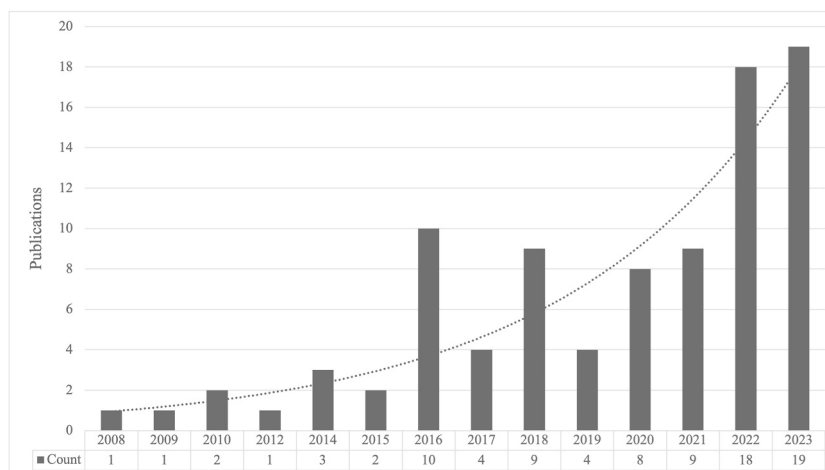


Fig. 2. Publication trends.

phase. A total of 27 articles were published, averaging 6.8 articles per year. This surge was largely driven by increased contributions in key journals, including the Journal of Cleaner Production, which published 11 articles, Business Strategy and the Environment, with 3 articles, and Sustainability, which also published 3 articles.

The third phase, labeled the "Development Phase," extends from 2020 to 2023. This period demonstrates continued expansion, with a growth rate of 69.3 percent compared to the second phase. This increase can be attributed to the growing academic contributions from journals such as Sustainability (69.3 percent increase), Business Strategy and the Environment (69.3 percent increase), and Climate and Development (109.9 percent increase). Additionally, new journals joined this conversation, including Corporate Social Responsibility and Environmental Management, International Journal of Climate Change Strategies and Management, Mitigation and Adaptation Strategies for Global Change, Frontiers in Environmental Science, and International Journal of Productivity and Performance Management. In total, 54 articles were published during this time, averaging 13.5 articles per year.

### 3.1.2. Publication by world regions

Table 2 and Fig. 3 present the distribution of research publications related to climate change and SMEs across different world regions. Table 2 includes the total publication count (TPP), percentage of publications (TPP percent), total citation count (TCC), and citations per paper (CPP) for each region. As illustrated in Table 2, Europe was the region with the largest number of publications (N = 69; 51.1 percent), followed by Asia (N = 30; 22.2 percent), Australia and Oceania (N = 12; 8.9 percent), Africa (N = 12, 8.9 percent), North America (N = 6; 4.4 percent), South America (N = 3; 2.2 percent), and Middle East (N = 3; 2.2 percent).

### 3.1.3. Publication by journals

A total of 42 journals have published research on this topic. Table 3 summarizes the top 10 journals that have published research on climate change strategies and SMEs. Notably, the Journal of Cleaner Production leads with 20 publications, representing 21.74 percent of the total sample, and has accumulated 623 citations, resulting in an average of 31.15 citations per article. Moreover, the Business Strategy and the Environment journal, with 10 publications (10.87 percent of the total), boasts the highest average citation per article at 46.50, indicating the significant impact of its articles. Sustainability ranks third with 9 publications (9.78 percent) and 144 citations, averaging 16 citations per paper. Other journals like Climate and Development and Corporate Social Responsibility and Environmental Management each contribute 5 publications (5.43 percent). Notably, Corporate Social Responsibility and Environmental Management stands out with a higher average citation count of 38.20, compared to Climate and Development's 12.60. Additionally, journals such as Mitigation and Adaptation Strategies for Global Change, Clean Technologies and Environmental Policy, Frontiers in Environmental Science, International Journal of Climate Change Strategies and Management, and International Journal of Productivity and Performance Management each have 2 publications (2.17 percent).

### 3.1.4. Publication by institution

A total of 177 academic institutions have published research on this topic. Table 4 highlights the top 10 universities that have contributed the most to research on climate change strategies and SMEs. The Democritus University of Thrace and the University of the Aegean in Greece lead with 4 publications each, representing 4.35 percent of the total sample. However, the University of the Aegean slightly outperforms in terms of impact with a higher citation count of 78 and an average of 19.50 citations per paper, compared to the Democritus University of Thrace's 73 citations and 18.25 citations per paper.

Kingston University London stands out with a citation count of 284 from just 3 publications (3.26 percent of the total), resulting in an average of 94.67 citations per paper, surpassing other universities in terms of average citations per publication. Other universities such as Hamburg University of Applied Sciences and Manchester Metropolitan University in Europe have 3 publications each (3.26 percent). However, they exhibit much lower citation averages of 7.67 citations per paper, indicating a more modest impact in this research area. The University of Queensland in Australia also has 3 publications, with a total citation count of 77, leading to an average of 25.67 citations per paper, positioning it as one of the higher-impact institutions outside Europe in this research area. Likewise, the University of Reading in the United Kingdom and the University of Thessaly in Greece have 3 publications each, with citation averages of 23.00 and 20.33, respectively. Finally, the Agricultural University of Athens in Greece and Jiangsu University in China have 2 publications each (2.17 percent) with average citations of 1.00 and 7.50 per paper, respectively.

**Table 2**

Publications by world regions.

| Region                | TPP | TPP percent | TCC  | CPP   |
|-----------------------|-----|-------------|------|-------|
| Europe                | 69  | 51.1        | 1564 | 22.67 |
| Asia                  | 30  | 22.2        | 460  | 15.33 |
| Australia and Oceania | 12  | 8.9         | 226  | 18.83 |
| Africa                | 12  | 8.9         | 149  | 12.42 |
| North America         | 6   | 4.4         | 194  | 32.33 |
| South America         | 3   | 2.2         | 105  | 35.00 |
| Middle East           | 3   | 2.2         | 18   | 6.00  |

Note: TPP = Total Publication Count; TPP percent Percentage of Total Publication. TCC = Total Citation Count; CPP= Citations per paper. Citation count obtained from Web of Science on March 2024.

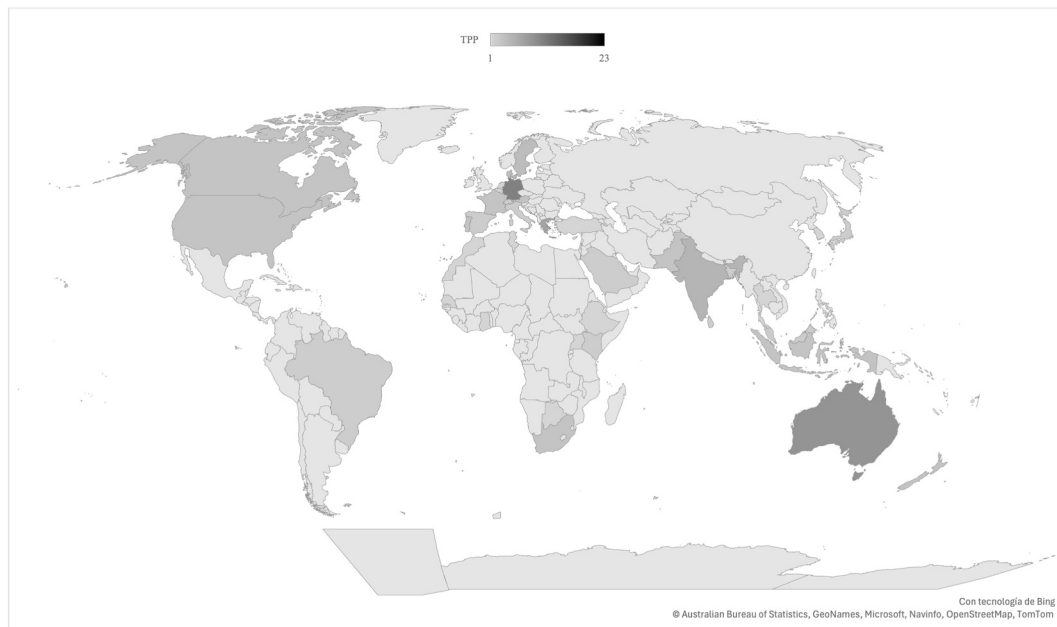


Fig. 3. Publication by world region.

Table 3

Top 10 Journals by publications-.

| Journal                                                           | TTP | TTP per cent | TCC | CPP   |
|-------------------------------------------------------------------|-----|--------------|-----|-------|
| Journal Of Cleaner Production                                     | 20  | 21.74        | 623 | 31.15 |
| Business Strategy and The Environment                             | 10  | 10.87        | 465 | 46.50 |
| Sustainability                                                    | 9   | 9.78         | 144 | 16.00 |
| Climate And Development                                           | 5   | 5.43         | 63  | 12.60 |
| Corporate Social Responsibility and Environmental Management      | 5   | 5.43         | 191 | 38.20 |
| Mitigation And Adaptation Strategies for Global Change            | 2   | 2.17         | 7   | 3.50  |
| Clean Technologies and Environmental Policy                       | 2   | 2.17         | 27  | 13.50 |
| Frontiers In Environmental Science                                | 2   | 2.17         | 4   | 2.00  |
| International Journal of Climate Change Strategies and Management | 2   | 2.17         | 6   | 3.00  |
| International Journal of Productivity and Performance Management  | 2   | 2.17         | 20  | 10.00 |

Note: TPP = Total Publication Count; TPP percent Percentage of Total Publication. TCC = Total Citation Count; CPP= Citations per paper. Citation count obtained from Web of Science on March 2024.

Table 4

Top 10 Institutions by publication.

| Organization                           | Country        | Region  | TTP | TTP per cent | TCC | CPP   |
|----------------------------------------|----------------|---------|-----|--------------|-----|-------|
| Democritus University Thrace           | Greece         | Europe  | 4   | 4.35         | 73  | 18.25 |
| University Aegean                      | Greece         | Europe  | 4   | 4.35         | 78  | 19.50 |
| Hamburg University of Applied Sciences | Germany        | Europe  | 3   | 3.26         | 23  | 7.67  |
| Kingston University London             | United Kingdom | Europe  | 3   | 3.26         | 284 | 94.67 |
| Manchester Metropolitan University     | United Kingdom | Europe  | 3   | 3.26         | 23  | 7.67  |
| The University of Queensland           | Australia      | Oceania | 3   | 3.26         | 77  | 25.67 |
| University of Reading                  | United Kingdom | Europe  | 3   | 3.26         | 69  | 23.00 |
| University of Thessaly                 | Greece         | Europe  | 3   | 3.26         | 61  | 20.33 |
| Agricultural University of Athens      | Greece         | Europe  | 2   | 2.17         | 2   | 1.00  |
| Jiangsu University                     | China          | Asia    | 2   | 2.17         | 15  | 7.50  |

Note: TPP = Total Publication Count; TPP percent Percentage of Total Publication. TCC = Total Citation Count; CPP= Citations per paper. Citation count obtained from Web of Science on March 2024.

**Table 5**

Top 10 authors by publications.

| Authors                   | TTP | TTP per cent | TCC | CPP   |
|---------------------------|-----|--------------|-----|-------|
| Skouloudis, Antonis       | 4   | 4.35         | 78  | 19.50 |
| Evangelinos, Konstantinos | 3   | 3.26         | 59  | 19.67 |
| Leal Filho, Walter        | 3   | 3.26         | 23  | 7.67  |
| Coles, Tim                | 2   | 2.17         | 55  | 27.50 |
| Dinan, Claire             | 2   | 2.17         | 55  | 27.50 |
| Halkos, George            | 2   | 2.17         | 59  | 29.50 |
| Hampton, Sam              | 2   | 2.17         | 29  | 14.50 |
| Khan, Adnan               | 2   | 2.17         | 15  | 7.50  |
| Thollander, Patrik        | 2   | 2.17         | 55  | 27.50 |
| Warren, Neil              | 2   | 2.17         | 55  | 27.50 |

Note: TPP = Total Publication Count; TTP percent Percentage of Total Publication. TCC = Total Citation Count; CPP= Citations per paper. Citation count obtained from Web of Science on March 2024.

### 3.1.5. Top authors by publications

A total of 287 scholars have published research on this topic. Table 5 provides information about the top individual researchers and the impact they have had in this field. The most prolific author is Professor Antonis Skouloudis (<https://orcid.org/0000-0002-3363-6692>, University of the Aegean, Greece), with 4 publications representing 4.35 percent of the total sample. His work has garnered 78 citations, resulting in an average of 19.50 citations per paper. Professor Konstantinos Evangelinos (University of the Aegean, Greece) and Professor Walter Leal Filho (<https://orcid.org/0000-0002-1241-5225>, Hamburg University of Applied Sciences, Germany) follow in the ranking, each with 3 publications representing 3.26 percent of the total sample. Notably, the highest citations per publication (CPP) observed was for Professor George Halkos (<https://orcid.org/0000-0002-2772-5306>, University of Thessaly, Greece), with a CPP of 29.50 based on 2 total publications (TTP = 2).

### 3.1.6. Top articles

Table 6 presents the top five most-cited articles across the two observed periods. Panel "a" in Table 6, encompassing the period 2008–2019, shows that the most-cited article is "Small Businesses and the Environment: Turning Over a New Leaf?" [47] with 245 citations, followed by "Sustainability Management and Small and Medium-Sized Enterprises: Managers' Awareness and Implementation of Innovative Tools" [48] with 125 citations. Subsequent articles in this period address key topics such as environmental management, circular economy, and energy efficiency in small and medium-sized enterprises. Besides, Panel "b" in Table 6, encompassing the period 2020–2023, shows that the most-cited article is "Circular Economy in Italian SMEs: A Multi-Method Study" [49] with 95 citations, followed by "An Analysis of Environmental Sustainability in Small & Medium-Sized Enterprises: Patterns and Trends" [50] with 40 citations. Other relevant articles in this period focus on sustainability management, environmental performance, and the adoption of new technologies to reduce greenhouse gas emissions.

### 3.1.7. Publications by research approach

The research approaches employed in the sample reveal a variety of methodologies for studying the phenomenon. 59.34 percent (N = 54) of the publications adopted a quantitative approach, while 14.29 percent (N = 13) employed a qualitative approach, and 9.89 percent (N = 9) utilized a mixed-methods approach. A smaller proportion investigated the phenomenon at a conceptual level (14.29 percent, N = 13) or experimental methods (2.20 percent, N = 2).

**Table 6**

Top articles by period.

| Panel a. Period 2008–2019.                                                                                                                                  |     |           |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----|-----------|
| Article                                                                                                                                                     | TCC | Reference |
| Small Businesses and the Environment: Turning Over a New Leaf?                                                                                              | 245 | [47]      |
| Sustainability Management and Small and Medium-Sized Enterprises: Managers' Awareness and Implementation of Innovative Tools                                | 125 | [48]      |
| Developing an extended theory of planned behavior model to explore circular economy readiness in manufacturing MSMEs, India                                 | 107 | [69]      |
| Motivating energy efficiency in small and medium enterprises                                                                                                | 72  | [74]      |
| Environmental Management, Climate Change, CSR, and Governance in Clusters of Small Firms in Developing Countries: Toward an Integrated Analytical Framework | 69  | [95]      |
| Panel b. Period 2020–2023.                                                                                                                                  |     |           |
| Article                                                                                                                                                     | TCC | Reference |
| Circular economy in Italian SMEs: A multi-method study                                                                                                      | 95  | [49]      |
| An analysis of environmental sustainability in small & medium-sized enterprises: Patterns and trends                                                        | 40  | [50]      |
| Sustainable environmental practices and financial performance: Evidence from listed small and medium-sized enterprises in the United Kingdom                | 36  | [77]      |
| Influencing factors on energy management in industries                                                                                                      | 35  | [99]      |
| Solar energy technology adoption and diffusion by micro, small, and medium enterprises: sustainable energy for climate change mitigation                    | 29  | [82]      |

Note: TCC = Total Citation Count.

Among the articles with empirical analyses ( $N = 86$ ), most examined SMEs across multiple economic sectors (46.51 percent,  $N = 40$ ) or focused on the secondary economic sector, specifically manufacturing and construction (37.21 percent,  $N = 32$ ). A smaller portion studied climate-related strategies in the primary sector, encompassing the raw materials industry (6.98 percent,  $N = 6$ ), and the tertiary sector, including the service industry (9.30 percent,  $N = 8$ ). Additionally, most studies analyzed data using regression analysis, including structural equation modeling (39.56 percent,  $N = 36$ ). A significant portion employed other quantitative methods such as descriptive statistics and variance methods like ANOVA (27.47 percent,  $N = 25$ ). In contrast, some articles utilized thematic analysis (13.19 percent,  $N = 12$ ), conceptual methods (7.69 percent,  $N = 7$ ), case studies (7.69 percent,  $N = 7$ ), and content analysis (2.20 percent,  $N = 2$ ). Notably, only 2 articles (2.20 percent) explored this phenomenon through experiments.

### 3.1.8. Publications by theoretical lenses

The articles within the sample generally align with broader trends of under-theorization in climate-related strategy research. Approximately 43.96 percent ( $N = 40$ ) of the articles did not adopt a specific theoretical lens, highlighting a predominant focus on empirical and practical insights rather than advancing or applying theoretical frameworks. Much of the research emphasizes regional or national case studies, often examining the perceived impact of climate change and extreme weather events on key economic sectors or industries (e.g., Refs. [51,52]). This practical orientation reflects a tendency to prioritize actionable knowledge for addressing climate-related risks over the development of robust theoretical foundations (e.g., Ref. [53]).

The remaining sample ( $N = 51$ ) utilized approximately 53 different theories, drawing from diverse disciplines. Specifically, theories from sociology accounted for 7.54 percent of the total (e.g., institutional theory, neo-institutional theory, legitimacy theory, and social capital theory), while those theories from psychology represented 5.66 percent (e.g., social cognitive theory, protection motivation theory, and theory of planned behavior). Theories rooted in organizations and management were the most prevalent, comprising 56.60 percent of the total (e.g., resource-based view, corporate social performance, green/sustainable supply chain management, resilience models, and stakeholder theory). Ethics-based frameworks accounted for 9.43 percent (e.g., theory of basic values, environmentalism, and shared value theory), and those from economic sciences contributed 20.75 percent (e.g., circular business models, technology acceptance and diffusion, economic agglomeration, and evolutionary game theory). Notably, no single theory emerged as dominant within literature, reflecting a lack of consensus on the most appropriate theoretical lens to explore this phenomenon. This theoretical fragmentation underscores the nascent and interdisciplinary nature of the field.

## 3.2. Science mapping

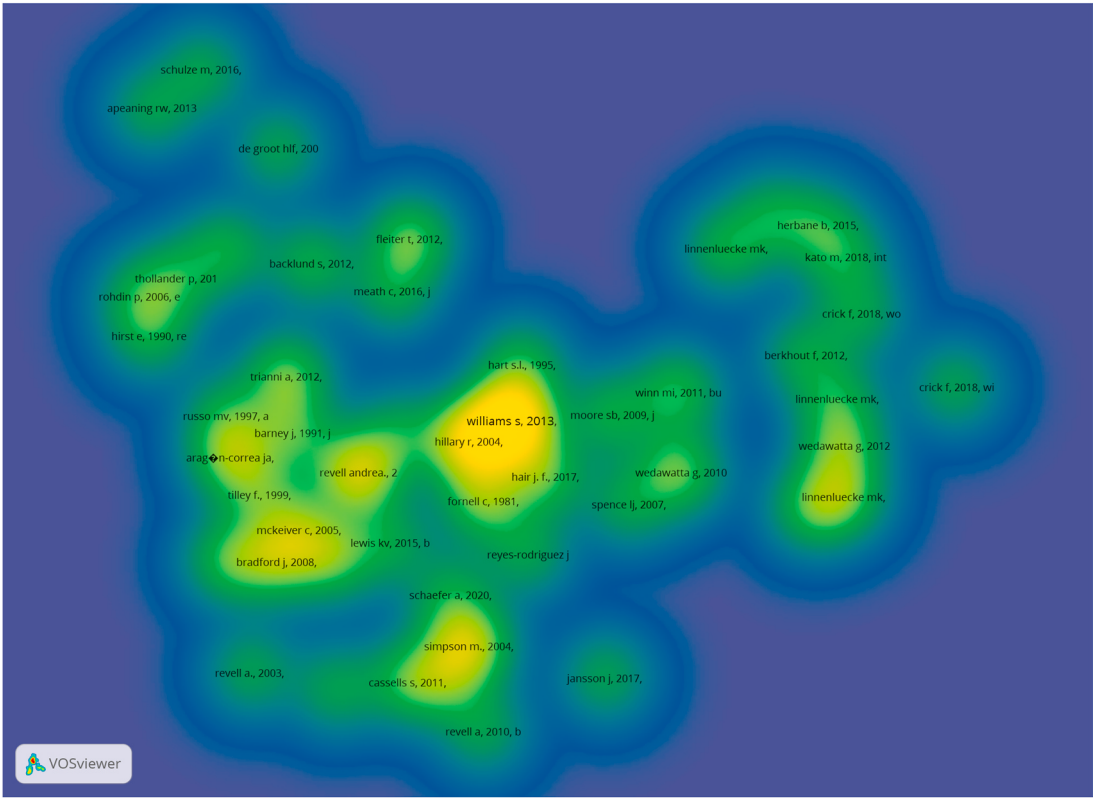
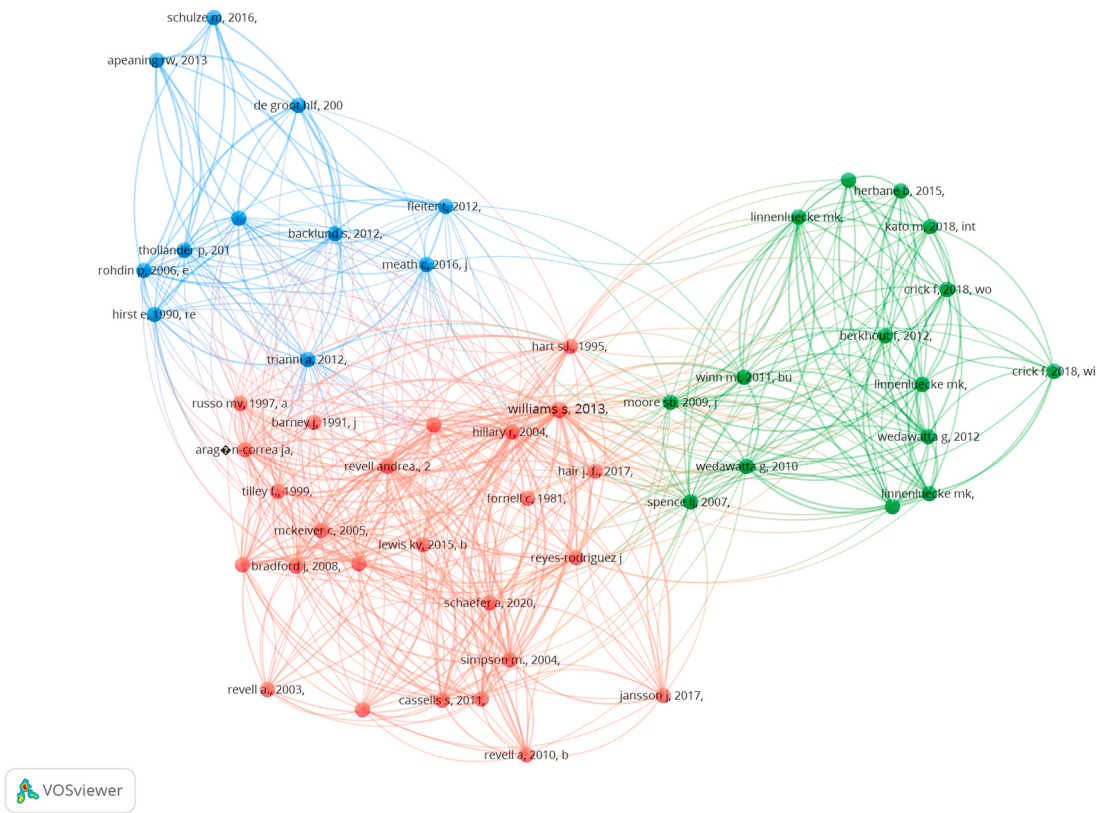
### 3.2.1. Co-citation network

To identify the intellectual foundations of the literature, we generated a co-citation network based on references (nodes with at least seven citations). The main component within that network is illustrated in Fig. 4, while the full network is described in the Supporting Information Table S1. Table 7 presents the most significant articles in each cluster based on citations. The first cluster, labeled "Managerial and Organizational Perspectives on Environmental Engagement" (see red nodes in Fig. 4), emphasizes the interplay between managerial values, organizational capabilities, and tailored strategies for environmental engagement. This cluster focuses on ethical, psychological, and organizational factors that drive sustainability practices in SMEs. It underscores the importance of leadership commitment, decision-making frameworks, and internal organizational mechanisms in shaping how firms respond to environmental challenges and integrate sustainability into their core operations [54–58].

Among the most cited articles within this cluster, Williams and Schaefer [54] and Simpson et al. [57] highlight the pivotal role of SME managers' values and beliefs in driving environmental engagement. This contrasts with the more frequently emphasized economic and external pressures as motivators. These studies demonstrate that personal commitment to environmental issues can lead to significant pro-environmental measures within small businesses, even when the economic benefits are perceived as ambiguous or minimal. While these studies underscore the influence of values and ethical foundations in shaping business responses to climate change, they also reveal a critical gap: how climate-related values are formed and whether these values are shared or generalized across the business community. The processes through which these values are developed, internalized, and transmitted within firms remain insufficiently explored, presenting an important avenue for future research.

Hillary [55] and Aragón-Correa et al. [58] explore the adoption of formal Environmental Management Systems (EMS) and proactive environmental strategies among SMEs. Both articles identify significant barriers to EMS adoption, such as limited resources, lack of expertise, and insufficient knowledge. However, they also highlight the potential benefits, including enhanced environmental performance, regulatory compliance, and competitive advantage. The studies emphasize the need for tailored approaches to support SMEs in implementing EMS, focusing on organizational capabilities like a shared vision, strategic proactivity, and resource alignment as critical factors for fostering successful environmental practices. Notably, both articles shed light on the divergent responses of SMEs to external environmental challenges, suggesting that their strategies are often shaped by contextual factors such as industry type, size, and market dynamics. Consequently, they propose that exploring subgroup differences and specific industrial characteristics represents a critical research gap in understanding how SMEs navigate these challenges.

Revell and Blackburn [56] expand on prior research by focusing on the business case for sustainability in SMEs, particularly within the construction and restaurant sectors. They uncover a common perception among SME owners that environmental and sustainability efforts offer limited benefits to their business operations, presenting a significant obstacle to the greening of these industries. This finding resonates with other studies, which collectively indicate that purely economic arguments may fall short in motivating environmental action, combining personal values, targeted support, and strategic organizational capabilities can encourage greater engagement with environmental and climate change issues. The article highlights a relevant research gap: understanding what drives



(caption on next page)

**Fig. 4.** Main component document-based co-citation network

Note. We have illustrated the network by retaining only those nodes with at least seven citations, allowing for a more parsimonious exploration of the communities within the network. A comprehensive description of the entire network is available in [Appendix Table A1](#).

**Table 7**

Co-citation network: Core articles per cluster.

| Reference | CL | LK | TLS | TCC | Main construct or theme                                                                                                          |
|-----------|----|----|-----|-----|----------------------------------------------------------------------------------------------------------------------------------|
| [54]      | 1  | 45 | 131 | 18  | Environmental engagement                                                                                                         |
| [55]      | 1  | 39 | 91  | 13  | Environmental performance (Green Certification Impact)                                                                           |
| [56]      | 1  | 31 | 85  | 12  | Environmental reform and environmental performance                                                                               |
| [57]      | 1  | 27 | 67  | 11  | Sustainable competitive advantages                                                                                               |
| [58]      | 1  | 29 | 53  | 8   | Organizational capabilities and strategic environmental strategies                                                               |
| [59]      | 2  | 28 | 62  | 8   | Resilience and supply chains against extreme weather events                                                                      |
| [2]       | 2  | 18 | 48  | 7   | Climate change strategy (Adaptation)                                                                                             |
| [60]      | 2  | 18 | 51  | 7   | Climate change strategy (Resilience, protection, adaptation, and risk management)                                                |
| [11]      | 2  | 23 | 47  | 7   | Climate change strategy (sustainability management, resilience, and adaptive organizational change)                              |
| [61]      | 2  | 18 | 41  | 6   | Social vulnerability and emergency management.                                                                                   |
| [62]      | 3  | 22 | 34  | 8   | Energy efficiency                                                                                                                |
| [63]      | 3  | 28 | 46  | 8   | Barriers to energy efficiency (including non-market failures, market failures, behavioral barriers, and organizational barriers) |
| [64]      | 3  | 21 | 40  | 6   | Energy efficiency, energy policies, barriers to energy efficiency, and energy management                                         |
| [65]      | 3  | 22 | 37  | 6   | Drivers of energy efficiency                                                                                                     |
| [66]      | 3  | 10 | 28  | 5   | Barriers and drivers of energy efficiency                                                                                        |

Note: CL= Cluster; LK = Total Links; TLS = Total Link Strength, TCC = Total Citation Count.

compelling environmental business cases in specific industries. Furthermore, the authors emphasize the importance of government involvement, suggesting that voluntary environmental initiatives by business actors often require external incentives or regulatory frameworks to gain traction. These insights call for more tailored and context-specific interventions to promote sustainability effectively, particularly within the diverse and resource-constrained SME landscape.

The second cluster, labeled “Building Resilience and Adapting to Climate Risks” (see green nodes in [Fig. 4](#)), centers on resilience-building, adaptation to extreme weather, and the development of robust strategies to address climate risks [2,11,59–61]. Among the most cited articles, Wedawatta et al. [59] underscore the importance of strengthening the resilience of construction sector SMEs to endure the impacts of extreme weather. They stress the need for policies that enhance SME resilience and coping mechanisms within supply chains. Similarly, Wedawatta and Ingirige [60] examine flood risk adaptation strategies among SMEs, identifying various property-level protection measures and business continuity strategies that enable SMEs to manage flood risks more effectively. Both studies illuminate a critical research gap: the need for frameworks and tools to assist SMEs in addressing environmental challenges. Specifically, they highlight the importance of developing decision-making tools designed for uncertain scenarios that threaten the survival of organizations. These tools and frameworks are essential to guide SMEs in navigating environmental risks, ensuring their adaptability and long-term resilience.

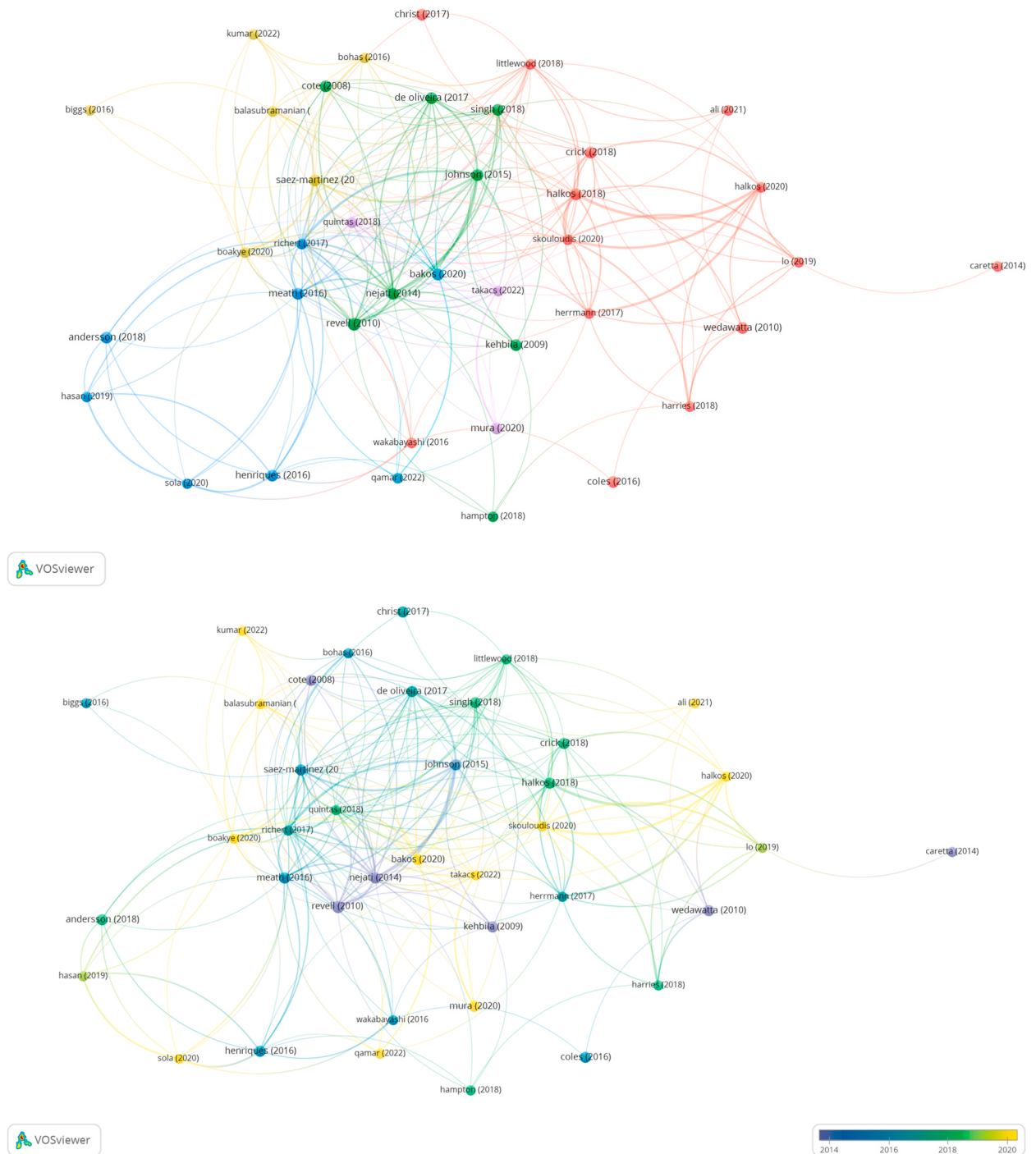
Besides, Linnenluecke et al. [2] thoroughly review firm and industry adaptation to climate change, highlighting the limited research on how businesses adjust to the evolving natural environment. Their work emphasizes the importance of cross-disciplinary approaches, integrating natural science insights into business strategies to effectively address climate change impacts. Similarly, Winn et al. [60] build on this concept by conceptualizing the organizational impacts of climate change. They propose a framework to understand and respond to the massive discontinuous changes caused by increasing climate-induced events such as storms, floods, and droughts. These articles collectively indicate that literature remains in an emergent stage, with significant gaps in understanding the internal and external mechanisms that drive firms to respond to environmental pressures. Specifically, both studies emphasize the critical need for tools and analytical frameworks to create and evaluate climate-related strategies, offering a pathway for businesses to align their operations with evolving environmental demands.

Lastly, the empirical analysis made by Chakraborty et al. [61] focused on social vulnerability to environmental hazards through a case study of population evacuation in hurricane-prone areas. Their findings revealed significant spatial variability in geophysical risk and social vulnerability, emphasizing the importance of tailored environmental planning. The study highlights the complexity of emergency management and evacuation strategies, advocating for approaches that consider the unique characteristics and needs of local populations. While this article examines a general case, its insights suggest the need to formulate and conceptualize climate-oriented strategies that account for perceived geophysical risks and potential vulnerabilities within business communities. Specifically, for SMEs, this underscores a critical literature gap regarding the development of dynamic and effective plans that integrate organizational constraints with external risk-related factors.

Finally, the third cluster, labeled as “Barriers and Enablers of Energy Efficiency” (blue cluster in [Fig. 4](#)) emphasizes the financial constraints, policy supports, and managerial drivers influencing the adoption of energy-efficient practices [62–66]. Within this cluster, research by Fleiter et al. [62] and Trianni and Cagno [63] identifies key barriers and determinants in adopting energy efficiency as a primary climate-related strategy. Their findings highlight that financial barrier, such as high investment costs and limited access to capital, are the most significant obstacles preventing SMEs from implementing energy-efficient programs. These financial challenges are further supported by Apeaning and Thollander [66], who emphasize how economic constraints and insufficient government

frameworks hinder energy efficiency in Ghanaian industries. These studies underscore the need for a deeper exploration of the persistent barriers SMEs face in adopting energy-efficient strategies. While the literature identifies common barriers—such as financial constraints (e.g., lack of capital, profitability concerns, transaction costs), technical and operational risks, and external pressures—there is no consensus on which factors most strongly shape organizational behavior.

Conversely, the articles also explore various drivers that can promote the adoption of energy-efficient practices. Backlund et al.



**Fig. 5.** Main component document-based bibliographic coupling network

Note. We have illustrated the network by retaining only those nodes with at least 15 citations, allowing for a more parsimonious exploration of the communities within the network. A comprehensive description of the entire network is available in [Appendix Table AII](#).

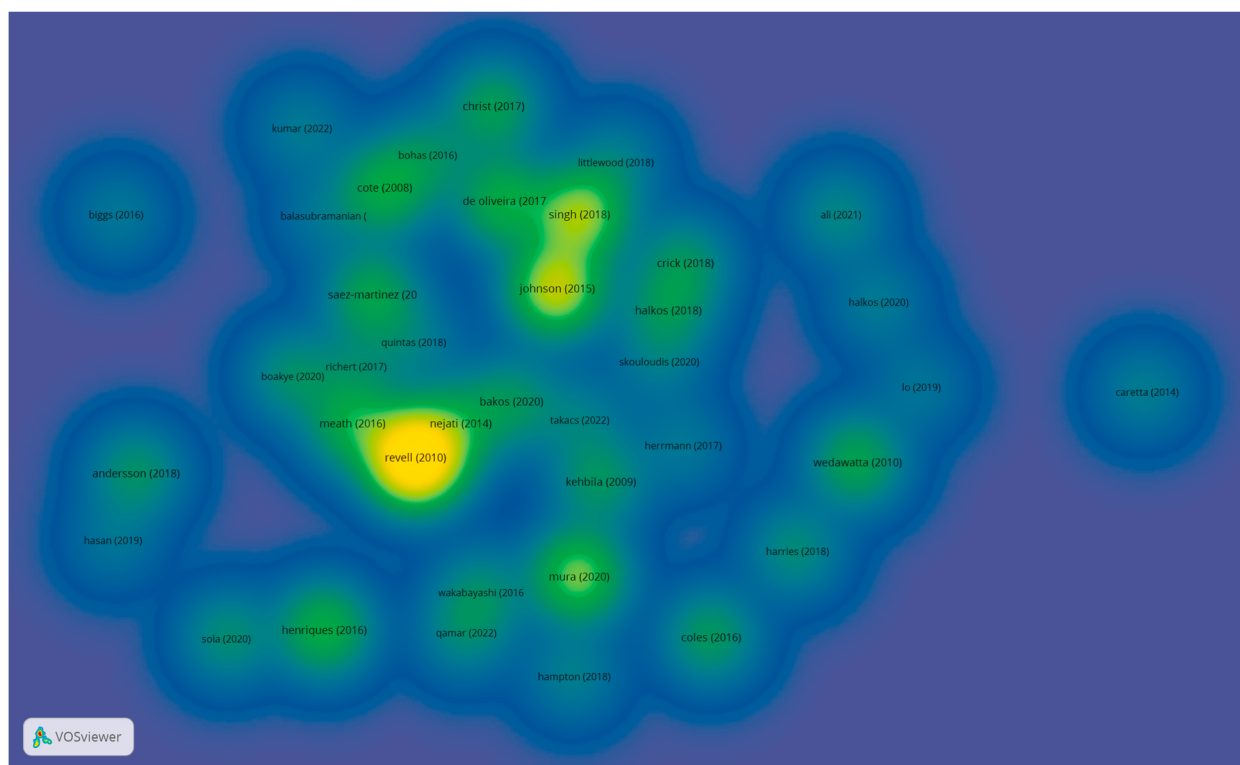


Fig. 5. (continued).

[64] advocate for the inclusion of continuous energy management practices alongside energy-efficient technologies to bridge the energy efficiency gap, suggesting that a holistic approach is essential for achieving significant energy savings. Cagno and Trianni [65] identify several drivers for energy efficiency in Italian SMEs, including public financing, external pressures (such as rising energy prices), and ambitious management. These findings suggest that supportive policies, financial incentives, and market pressures can effectively encourage SMEs to invest in energy-efficient measures. While these articles highlight potential drivers for adopting energy-related strategies, they also point to a gap in understanding how organizations perceive and respond to external pressures when formulating their climate-related strategies. Specifically, while the studies suggest that policies and external pressures can motivate action, how these drivers are perceived and leveraged by SMEs remains unclear. Furthermore, although the need for policy instruments is recognized, there is little guidance on how such instruments should be formulated and implemented to effectively motivate SMEs to adopt energy-efficient practices.

### 3.2.2. Bibliographic coupling network

Subsequently, we conducted a bibliographic coupling analysis to identify the research fronts of this field. Fig. 5 illustrates the observed clusters within the main component of the bibliographic coupling network (nodes with at least 15 citations). The full network is described in the Supporting Information Table S2. Additionally, Table 8 provides a list of the top-cited papers within each cluster.

Cluster 1, labeled "Building Resilient Enterprises," examines how vulnerability, collaboration, and organizational capacities influence SMEs' resilience to climate challenges (See red nodes in Fig. 5) [59,67,68]. Most articles in this cluster (78.57 percent) employ quantitative methods, such as regression analysis, to explore resilience-related phenomena. Notably, the geographical focus of these studies spans Europe, Australia, Oceania, Asia, and Africa, with limited coverage of The Americas, representing a significant research gap. The most cited paper in this cluster, Wedawatta et al. [59], investigates how SMEs face extreme weather events by examining the interrelation between vulnerability, coping strategies, and organizational coping capacities. Their research highlights the subsequent impact of these factors on SMEs' resilience levels, offering a comprehensive framework to analyze climate challenges in the context of supply chains.

The second most cited paper, Christ et al. [67], focuses on cooperative strategies employed by SMEs to address climate-related risks. The study finds that sustainable cooperation is driven by balanced power dynamics, aligned mutual objectives, shared risks and benefits, and established trust between collaborating firms. The third key paper, Coles [68], explores climate-related strategies and energy practices in the tourism sector, emphasizing the role of SMEs in adapting to climate change within this industry. Despite these contributions, this cluster identifies a critical gap in understanding how various barriers and drivers shape the determinants of resilience at the organizational level. Specifically, the literature has yet to fully address the mechanisms through which SMEs adapt their processes and strategies to respond effectively to climate-related risks. Further research is needed to bridge this gap by identifying

**Table 8**  
Bibliographic coupling network: Core articles per cluster.

| Article | CL | TCC | Research Aim                                                                                                                                                                                | Method                                                                         | Main Finding                                                                                                                                                                                                                                                                                                                           |
|---------|----|-----|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [59]    | 1  | 58  | To develop a decision-making framework that can be used by construction SMEs to enhance their resilience to Extreme Weather Events.                                                         | Integrative Literature Review                                                  | The authors developed a conceptual framework that details the impact of Extreme Weather Events and their role in shaping the interrelated relationship between a) Vulnerability, b) Coping Strategies, and c) Coping Capabilities, and their collective influence on the Organizational Resilience Level.                              |
| [67]    | 1  | 52  | To explore how cooperation aids companies toward sustainable business outcomes.                                                                                                             | Case Study Analysis                                                            | The case analysis suggests that cooperative strategies emerge when organizations effectively balance their objectives, needs, risks, and resources, and cultivate trust over time.                                                                                                                                                     |
| [68]    | 1  | 46  | To examine how SMEs have responded to climate change and their energy practices.                                                                                                            | Mixed Research Based on 417 Surveys, 18 Interviews, and 29 Case Studies        | Energy literacy among firms was low. Most respondents did not proactively manage energy as a critical resource, reflecting limited awareness about environmental behavior and organizational impact.                                                                                                                                   |
| [47]    | 2  | 245 | To identify the main barriers and drivers of environmental reforms and to explore how owners and managers perceive policy initiatives related to their environmental performance.           | Mixed Research Based on 220 Surveys, and 10 Interviews.                        | Most respondents were proactively engaged in measures to reduce their environmental impact. The primary driver for these actions was the owners' concern for the environment. The main barriers identified were poor infrastructure, increased costs, and a perceived loss of competitiveness in the market.                           |
| [48]    | 2  | 125 | To investigate the rates of awareness and implementation of sustainability management tools in SMEs.                                                                                        | Regression Analysis based on data from 176 firms                               | Respondents had a relatively low awareness and implementation level. Awareness and implementation levels had a highly positive correlation. Larger SMEs are more likely to adopt sustainability management tools.                                                                                                                      |
| [69]    | 2  | 107 | To investigate how attitudes, social pressures, perceived behavioral control, environmental commitment, and green economic incentives influence the adoption of circular economy practices. | Regression Analysis based on data from 248 firms                               | Strong attitudes increased social pressure, green economic incentives, and environmental commitment promote circular economy readiness. Conversely, perceived behavioral control was identified as an impediment to adopting the circular economy.                                                                                     |
| [74]    | 3  | 72  | To identify and discuss the barriers to energy efficiency in the industrial sector.                                                                                                         | Case Study Analysis                                                            | Energy efficiency barriers vary depending on company size, type of activity, energy intensity, and ownership structure. Additionally, significant behavioral barriers include limited time, information, and cognitive capacity.                                                                                                       |
| [75]    | 3  | 63  | To assess the motivating factors and barriers that impacted energy savings behavior.                                                                                                        | Quantitative analysis of 220 firms                                             | SMEs are mostly motivated by factors such as financial, environmental, and compliance-driven elements. However, they are constrained by management, organizational characteristics, premises, and staff.                                                                                                                               |
| [72]    | 3  | 40  | To develop a method to calculate an energy efficiency index for the estimation of industrial SMEs' total energy performance.                                                                | Quantitative analysis of 31 firms                                              | The authors propose an energy efficiency index to benchmark the energy performance of industrial small and medium-sized companies' support and production processes.                                                                                                                                                                   |
| [76]    | 4  | 58  | To explore the drivers of corporate environmental responsibility (CER) in SMEs and to investigate whether corporate environmental responsibility has any effect on SME performance.         | Regression Analysis based on data from 3647 firms                              | The results suggest that most managers perceive no clear benefits from engaging in environmental behavior. Moreover, entrepreneurs' values and personal commitment to environmental issues are closely linked to company behavior.                                                                                                     |
| [77]    | 4  | 36  | To identify what are the financial implications of sustainable environmental practices                                                                                                      | Regression Analysis based on data from 201 firms                               | The empirical examination found a nonlinear relationship between sustainable environmental practices and financial performance.                                                                                                                                                                                                        |
| [78]    | 4  | 33  | To examine the effect of Corporate Social Responsibility in the Adoption of Green Information Technology                                                                                    | Regression Analysis based on data from 815 firms                               | The examination points to a positive effect of strategic CSR on the likelihood of adopting "reduce" green IT while negatively impacting "transform" green IT adoption.                                                                                                                                                                 |
| [49]    | 5  | 95  | To understand what actions SMEs are taking to meet the challenges and opportunities of the Circular Economy.                                                                                | Mixed Research Based on 209 Surveys, 5 In-depth interviews, and 4 Focus groups | The results suggest that the circular economy entails a systematic approach to strategic value creation through the integration of various environmentally driven policies and processes. Moreover, SMEs face several external barriers, such as the lack of regulation and guidelines regarding its implementation. Lastly, incentive |

(continued on next page)

Table 8 (continued)

| Article | CL | TCC | Research Aim                                                                                                            | Method                                           | Main Finding                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|---------|----|-----|-------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| [80]    | 5  | 22  | To develop a holistic framework that considers the internal barriers companies face when adopting circular economy.     | Grounded Theory Analysis Based on 59 Interviews. | schemes and economic incentives are significant drivers of the circular economy. SMEs face six company-internal barriers (i.e., risk aversions, short-term orientation, economically dominated thinking, unwillingness to engage in trade-offs, Shortage of resources, Lack of Knowledge) and four macro-external barriers (i.e., technology, market, legislative, and society and consumers). Lastly, six sustainable management strategies are suggested. |
| [81]    | 5  | 20  | To explore how SMEs include decarbonization in their Business Model and to explore the size effect.                     | Quantitative Analysis Based on 1161 Firms        | There is a significant difference in the adoption of practices related to decarbonization among SMEs. Additionally, SMEs are adopting relatively few practices to reduce greenhouse gas emissions.                                                                                                                                                                                                                                                          |
| [50]    | 6  | 40  | To review recent studies on environmental sustainability in SMEs                                                        | Integrative Literature Review                    | The review highlights the main drivers and barriers to environmental sustainability. Internal drivers, such as economic benefits and stakeholder support, are emphasized as key motivations for implementation. Government regulations are considered an external driver for the adoption of sustainability practices.                                                                                                                                      |
| [82])   | 6  | 29  | To identify and analyze the drivers and barriers to the adoption and diffusion of independent solar photovoltaic panels | Regression Analysis based on data from 129 firms | The adoption of alternative technologies was mostly constrained by factors such as their price, energy cost intensity, and organizational size.                                                                                                                                                                                                                                                                                                             |

Note: CL= Cluster; TCC = Total Citation Count.

actionable pathways that SMEs can take to enhance their resilience to environmental challenges.

Cluster 2, labeled "Institutional and market dynamics of sustainability," explores how external pressures such as institutional environments and market structures influence sustainable practices (see green nodes in Fig. 5) [47,48,53,69–73]. Approximately 75 percent of the articles within this cluster focus on Europe and Asia, leaving regions like Africa, The Americas, Australia, and Oceania largely underexplored. This geographical limitation highlights an opportunity for further research into these underrepresented regions. The most cited paper in this cluster, Revell et al. [47], examines the environmental impact of SMEs in the United Kingdom, identifying the main barriers and drivers of environmental reforms. The study found that SME owners and managers generally held positive attitudes toward environmental actions and were actively engaged in reducing their environmental footprints. Interestingly, the study revealed that the primary driver of these efforts was personal concern for the environment among respondents, rather than external pressures like market demand or regulations.

The second most cited paper in Cluster 2 is Johnson [48], which applied the stages of innovation diffusion theory to examine awareness and implementation rates of sustainability management tools among German manufacturing SMEs. The study found that awareness and implementation levels were low, with larger SMEs demonstrating a higher likelihood of adopting these tools. Moreover, SMEs that became aware of the financial benefits of sustainability management tools were more motivated to implement them. The third most cited paper, Singh et al. [69], utilized the Theory of Planned Behavior (TPB) to explore the drivers of circular economy adoption in Indian SMEs. The findings indicated that attitudes, social pressures, perceived behavioral control, and green economic incentives significantly influence the readiness of SMEs to adopt circular economy practices. Additionally, a strong sense of environmental commitment emerged as a critical driver in these firms' transition to circular economy models. These articles underscore the key role of innovation and R&D adoption in driving sustainability at the organizational level. They highlight the importance of continuous efforts by SMEs to search for suitable knowledge, practices, and technologies to "green" their firms. However, the interplay of mechanisms that facilitate this process, including knowledge transfer, technological adaptation, and market exploration, remains an open line of inquiry.

Cluster 3, labeled "Energy efficiency and organizational strategy," examines patterns of energy use, stakeholder influence, and the barriers to adopting energy-efficient technologies (see blue nodes in Fig. 5) [72,74,75]. This cluster reveals that 50 percent of the studies focus on the European context, with limited evidence from Australia, Oceania, Asia (e.g., Pakistan), and Africa (e.g., South Africa). Notably, The Americas lacks compelling research, highlighting a significant geographical literature gap. Moreover, a substantial portion of the research in this cluster lacks a clear theoretical framework, leaving room for the integration of novel frameworks to deepen understanding. The most cited paper in this cluster, Henriques and Catarino [74], investigates the barriers and motivations associated with energy efficiency in the industrial sector through the Portuguese case study "Energy Efficiency in Small and Medium-sized Enterprises" (EFINERG). The study identifies several constraining factors, including company characteristics (i.e., size, type of activity, and sector), energy-specific issues (i.e., energy intensity and electricity supply challenges), and structural factors (i.e., ownership structure and organizational priorities). Additionally, the study underscores major barriers faced by SMEs, such as limited time, lack of information, and insufficient cognitive capacity to engage with and implement energy efficiency programs.

The second most cited paper, Meath [75], leverages literature on factors influencing the adoption and innovation of energy efficiency to assess the motivating factors and barriers affecting energy-saving behaviors in SMEs. This study focuses on firms participating in the ClimateSmart Business Cluster Program in Australia, identifying three primary motivators: financial incentives (e.g., cost

savings), environmental considerations (e.g., reducing carbon footprints), and regulatory compliance. Despite these motivators, SMEs face significant constraints due to their organizational characteristics, premises, and staff limitations, which hinder the adoption of energy-efficient practices. The third most cited paper, Andersson [72], proposes and empirically assesses an energy efficiency index, focusing on organizations participating in the Swedish Energy Audit Program (SEAP). The study provides a benchmarking value for energy efficiency across various industries, offering a quantitative tool for evaluating and comparing energy performance. Both articles, alongside others in this cluster, highlight a critical gap in understanding the role of informal institutions—such as culture—in shaping the adoption of energy-efficient practices. While culture has been recognized as a key driver of managerial perceptions and decision-making, its influence on how managers perceive and respond to climate pressures remains underexplored.

Cluster 4, labeled “Integrating Environmental and Financial Goals,” investigates the interplay between environmental practices and financial performance, with a focus on leadership and organizational transformation (yellow nodes in Fig. 5) [76–79]. This cluster predominantly explores SMEs in Europe (e.g., the United Kingdom), Asia (e.g., China and Turkey), and Africa, leaving significant gaps in contextual settings such as The Americas, Australia, and Oceania. The most cited paper within the cluster is Saez-Martinez et al. [76], which, using Corporate Social Responsibility Theory, explored the drivers of Corporate Environmental Responsibility in SMEs and how they affect organizational performance. The results suggest that most C-level executives perceive no clear organizational benefit in adopting an environmentally driven corporate strategy. However, market pull, and regulatory frameworks are identified as external drivers linked to CER. Lastly, the authors did not find a significant effect of environmental responsibility on financial performance, as measured by sales growth.

The second most cited paper, Boakye et al. [77], drawing on the Natural Resource-Based View and Stakeholder Theory, tested the relationship between environmental practices and financial performance. Their results indicate a nonlinear relationship between sustainable environmental practices and financial performance, as measured by Return on Assets and Tobin's Q. The third most cited paper is Bohas and Poussing [78], which examined the role of corporate social responsibility in the adoption of green information technologies. Their empirical examination suggests that strategic corporate social responsibility positively affects the likelihood of adopting “reduce” green information technologies while negatively impacting “transform” green information technology adoption. Additionally, the probability of adopting green information technologies is positively influenced by cost savings and corporate image. In sum, articles within this cluster highlight a significant gap in understanding the link between endorsing climate-related strategies and their subsequent impact on organizational-level outcomes. While several studies explore the motivations for adopting environmentally responsible practices, there is limited research on how these actions translate into tangible benefits for SMEs, particularly in terms of long-term organizational performance. Addressing this gap would be crucial in helping policymakers and business leaders craft strategies that not only promote environmental sustainability but also demonstrate clear financial or operational gains.

Cluster 5, titled “Innovations in Circular and Low-Carbon Business Models,” explores pathways for adopting regenerative and decarbonized business practices, emphasizing how organizations can transition to more sustainable models (see purple nodes in Fig. 5) [49,80,81]. Research in this cluster predominantly utilizes quantitative regression-based empirical methods, leaving exploratory inductive research underutilized. The research has been heavily focused on Europe (e.g., Spain and France) and Asia (e.g., Pakistan), with relatively little attention paid to other regions such as The Americas, Africa, Australia, and Oceania. The most cited article within Cluster 5, Mura [49], investigates the determinants of circular economy adoption among SMEs. The study reveals that organizations typically engage in a systematic approach, endorsing various practices and processes aligned with the principles of the circular economy. Key findings highlight that while many SMEs recognize the value of practices in circular economy, they face significant barriers, including a lack of regulatory and practical guidelines necessary for effective implementation. Additionally, the research emphasizes the importance of economic incentives as crucial drivers for motivating SMEs to adopt circular economy initiatives.

The second most cited article, Takacs et al. [80], aimed to develop a holistic framework for understanding the internal and external barriers that hinder the adoption of circular economy practices. Through the exploration of 59 firms across three industries, the study identified six internal barriers (e.g., lack of resources, organizational inertia, knowledge gaps) and four external barriers (e.g., regulatory complexity, market limitations). These barriers interrelate, shaping organizational concerns and resistance to adopting circular economy initiatives. The third most cited article, Quintas et al. [81], focused on how SMEs incorporate decarbonization practices into their business models. Their research highlights a disparity in the adoption of voluntary decarbonization practices based on firm size, with larger SMEs more likely to adopt such practices compared to smaller ones. Furthermore, SMEs were found to assign moderate importance to regulatory compliance in shaping their value propositions, indicating that external regulations play a role but are not a primary motivator for most firms. Articles in this cluster point to a critical gap in understanding how firm-level practices, such as corporate social responsibility and green processes influenced by external pressures (e.g., regulations, market demands), drive the adoption of circular and low-carbon business models. Additionally, this cluster highlights the importance of exploring how firms integrate environmental value creation into their strategic planning, emphasizing the need for frameworks that bridge organizational practices with broader sustainability goals.

Lastly, Cluster 6, labeled “Operationalizing Sustainability in SMEs” (see light blue nodes in Fig. 5), investigates firm-level factors and technologies that enable SMEs to adopt sustainable business strategies. This cluster is anchored by two core papers [50,82] that focus on empirical studies conducted in the Asian context. Importantly, this cluster is the least explored, with significant gaps in research addressing other contextual settings, such as the Americas, Europe, or Africa. Bakos et al. [50] conducted a review of recent studies on environmental sustainability in SMEs, identifying a blend of internal and external factors as key drivers and barriers. Among the core drivers, the study highlights government regulations, potential economic benefits, and stakeholder support as pivotal in promoting environmental sustainability practices. Conversely, barriers include limited financial resources and insufficient technical expertise, which constrain SMEs' ability to implement sustainable measures. Qamar et al. [82] focused on analyzing the factors influencing the adoption of solar energy technologies within the SME context. Their findings underscore the significant roles of

technology price, energy costs, and organizational size in determining the likelihood of adopting environmentally driven technologies. The study emphasizes that smaller firms often face challenges related to high upfront costs and a lack of access to affordable technology, whereas larger organizations tend to have more capacity to integrate these technologies into their operations. Both articles point to the need for further exploring the process by which SMEs engage in environmentally driven business models.

### 3.3. Main insights performance analysis

In summary, we provide a comprehensive overview of climate change strategies in SMEs from 2008 to 2023. This includes an in-depth analysis using various performance analysis tools, such as examining productivity trends (Fig. 2), analyzing publication patterns across world regions (Table 2), identifying the leading journals in the conversation (Table 3), highlighting key institutions researching this topic (Table 4), recognizing influential authors (Table 5), showcasing the most cited articles (Table 6), mapping co-citation networks (Table 7), and identifying core articles through bibliographic coupling networks (Table 8).

Overall, we observed that the number of articles on climate change strategies for SMEs has entered the "Development Phase," suggesting a potential surge in the literature in the coming years. This signals the growing interest in this topic between scholars and the broader community. Our findings show that the leading countries exploring this phenomenon are the United Kingdom (N = 23, 17.04 percent), Germany (N = 11, 8.15 percent), and Australia (N = 9, 6.67 percent), with Europe accounting for the highest number of publications (N = 69, 51.1 percent). In contrast, regions like South America (2.2 percent), Central America (0 percent), North America (4.4 percent), and the Middle East (2.2 percent) show low research participation. These results highlight the need for a global perspective on this topic, especially given the increased pressure on SMEs to contribute to the UN's Sustainable Development Goals. Exploring how SMEs address climate-related challenges within their unique institutional and economic contexts is critical for future research.

Lastly, Democritus University of Thrace (Greece, N = 4) and the University of the Aegean (Greece, N = 4) are the institutions with the highest number of published articles on this topic. The most active journals include the Journal of Cleaner Production (N = 20, 21.74 percent) and Business Strategy and the Environment (N = 10, 10.87 percent). Additionally, the most prolific authors during this period are Prof. Antonis Skouloudis (Scopus Author ID: 26635942200), Prof. Konstantinos Evangelinos (Scopus Author ID: 10038987600), and Prof. Walter Leal Filho (Scopus Author ID: 6602389932). These findings suggest that advancing our understanding of climate change strategies in SMEs will require increased international collaboration within the academic community. Furthermore, the concentration of discussions in a few key journals highlights the need to expand this conversation to other general and specialized outlets, offering more diverse perspectives on how SMEs can address climate-related challenges.

### 3.4. Delving into the contextual differences shaping SMEs' climate-related strategies

Understanding how institutional, cultural, regional, and sector-specific contexts shape climate-related strategies in SMEs requires a multi-faceted approach. At the firm level, existing research emphasizes the importance of organizational and managerial antecedents, such as attitudes, perceptions, and decision-making frameworks among top managers [82]. These factors play a pivotal role in shaping SMEs' ability to respond to climate-induced risks and align their environmental strategies with broader organizational goals. For instance, the extent to which SMEs adopt sustainable practices is often influenced by internal drivers like perceived economic benefits, stakeholder pressures, and resource availability [16,67,83,84]. However, company-internal barriers [50]—such as risk aversion, short-term orientation, limited knowledge, and resource shortages—often limit the scope and effectiveness of these strategies [3]. This underscores the need for targeted interventions that enhance organizational awareness, resource capabilities, and managerial competencies to overcome these hurdles.

Contextual factors at the macro level also profoundly impact SMEs' climate strategies, revealing significant regional disparities and socio-economic influences. Institutional frameworks, including government regulations, legislative guidelines, and incentive schemes, act as critical external drivers for sustainable behavior [83,85]. However, in many regions, SMEs face structural barriers [47,49], such as inadequate infrastructure, weak regulatory frameworks, overwhelming bureaucracy, and a lack of incentives, which can undermine their efforts to adopt climate-related strategies. For instance, while high-income countries benefit from robust institutional support and advanced technological ecosystems, SMEs in both low- and middle-income regions [86–89] often contend with higher costs, limited access to sustainable technologies, and a perceived loss of competitiveness when adopting alternative practices. Furthermore, sector-specific challenges, such as the energy intensity of operations or the reliance on carbon-intensive supply chains [90,91], exacerbate these issues, particularly in industries within the primary and secondary economic sectors.

Cultural and societal factors add another layer of complexity, influencing how SMEs perceive and prioritize climate action. National cultural patterns and consumer preferences shape the adoption of environmentally sustainable business models [92], while social capital and community engagement often determine the effectiveness of collective climate responses [53,93]. SMEs operating in regions with high environmental awareness or strong societal support for sustainability are more likely to integrate environmental strategies into their operations [94]. In contrast, those in regions with weaker social and cultural emphasis on sustainability may struggle to justify the costs of such transitions.

The interplay between institutional and economic contexts further highlights the importance of addressing both drivers and barriers to environmental behavior [62–66]. Poor infrastructure [47], economically dominated thinking, and unwillingness to engage in trade-offs [95] are among the key barriers that hinder SMEs from achieving sustainability goals. Yet, economic incentives and stakeholder support emerge as crucial enablers, suggesting that well-designed public policies and incentive structures can play a transformative role [16,96,97]. For example, reducing the price and cost intensity of sustainable technologies [17] and providing clear

regulatory frameworks could significantly enhance SMEs' ability to adopt alternative environmental practices [49,95]. International collaboration within the academic and policy communities is essential to developing solutions that address these regional and sector-specific disparities.

To advance the field, future research should focus on the nuanced relationships between institutional contexts, cultural influences, and SME strategies. Investigating the socio-economic traits that foster climate adaptation, such as social capital and institutional trust, could provide valuable insights into effective policy design. Additionally, expanding the conversation beyond concentrated academic and policy circles to include diverse perspectives is critical. By aligning global efforts with regional specificities, we can better equip SMEs to navigate climate-related challenges while contributing meaningfully to the UN's Sustainable Development Goals.

## 4. Discussion

### 4.1. Research agenda

Seeking to propose a research agenda, we illustrated the trends and foundations of the literature through the analysis of co-occurrence and bibliographic coupling networks. This research agenda aims to provide a comprehensive roadmap for advancing theoretical and practical understanding of SMEs' climate-related strategies, addressing critical gaps while fostering innovation in this rapidly evolving field. In the co-citation network, we identified three clusters: Managerial and Organizational Perspectives on Environmental Engagement (it focuses on the ethical, psychological, and organizational factors shaping pro-environmental behaviors and decisions); Building Resilience and Adapting to Climate Risks (it investigates systemic and stakeholder-driven approaches for SMEs to develop adaptive capacity and resilience); and Barriers and Enablers of Energy Efficiency (it explores the determinants, challenges, and enablers of implementing climate strategies at the organizational level).

Additionally, the bibliographic coupling network revealed six clusters: Building Resilient Enterprises (it examines how vulnerability, collaboration, and organizational capacities influence resilience to climate challenges); Institutional and Market Dynamics of Sustainability (it investigates how external pressures, such as institutional environments and market structures, shape sustainable practices); Energy Efficiency and Organizational Strategy (it explores patterns of energy use, stakeholder influence, and barriers to adopting energy-efficient technologies); Integrating Environmental and Financial Goals (it analyzes the interplay between environmental practices and financial performance, focusing on leadership and organizational transformation); Innovations in Circular and Low-Carbon Business Models (it identifies pathways for adopting regenerative and decarbonized business practices); and Operationalizing Sustainability in SMEs (it examines firm-level factors and technologies that drive sustainable business strategies). Based on the above clusters, we propose several avenues for further research. Table 9 provides an overview of these potential research paths, highlighting opportunities for deeper exploration in each area of inquiry.

Considering our overview, policymakers could benefit from research that identifies conditions under which climate strategies yield sustainable competitive advantages, helping to build compelling business cases for climate action. Scholars should adopt systems perspectives to examine SMEs' behaviors within socio-ecological contexts, emphasizing transformative change and adaptive capacity. Studies can explore how firms balance stakeholder trade-offs and the costs of adaptation versus inaction. Moreover, partnerships and institutional developments warrant attention to understanding how SMEs gain the attributes necessary to respond effectively to climate disruptions.

Furthermore, barriers to energy efficiency remain underexplored, particularly in SMEs. Therefore, research should develop taxonomies of these barriers and quantify the energy efficiency gap, investigating how policies can bridge this divide. Additionally, firm-specific characteristics such as size, innovation patterns, and sectoral differences could be analyzed to uncover determinants of energy-efficient practices. Public policies that either facilitate or hinder energy efficiency improvements also merit further exploration. Future research should investigate the relationship between organizational vulnerability, extreme weather coping strategies, and resilience. Exploring how firms collaborate or compete to address climate risks can shed light on collective and competitive dynamics. Moreover, identifying cognitive and capability-based antecedents to energy management strategies could help advance theories of resilience in SMEs.

Understanding the role of national institutional environments and market sophistication in shaping sustainability practices is another promising area of inquiry. Future research could explore how logistics systems influence the implementation of sustainable strategies, as well as how cultural patterns drive the adoption of environmentally sustainable business models. Further studies should assess how stakeholder pressures and environmental challenges influence strategic energy decisions in SMEs. By analyzing energy consumption patterns across industries, researchers can highlight the dual role of energy as a cost driver and a performance metric. Additionally, addressing barriers to proactive climate-related strategies could provide actionable insights for both businesses and policymakers.

The interplay between environmental practices and financial outcomes also requires deeper investigation. Research could examine how leadership values and cognitive biases shape climate-related strategies. Furthermore, studies should explore how firms transform their competencies to respond to perceived climate risks and how these changes impact financial performance. There is also a need to identify factors that drive the adoption of low-carbon and circular economy models in SMEs. Research could focus on corporate-level determinants of decarbonization practices, as well as the environmental barriers impeding such transitions. Finally, future research should explore the technological and organizational factors influencing SMEs' adoption of climate-related technologies. Finally, comparative studies across regions could uncover how firms navigate varying regulatory and economic landscapes to implement sustainable practices effectively.

**Table 9**

Future research directions.

| Cluster                                                                | Conceptual Perimeter                                                                                                 | Underlying Rationale                                                                        | Potential Avenues                                                                                                                       | Theoretical Value                                                                                                              | Possible Research Questions                                                                                                                                             | Reference     |
|------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------|---------------------------------------------------------------------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------|---------------|
| Managerial and Organizational Perspectives on Environmental Engagement | Focuses on ethical, psychological, and organizational factors influencing pro-environmental behaviors in SMEs.       | Addresses the gap in understanding intrinsic motivators behind SMEs' environmental actions. | Challenges the assumption that external pressures primarily drive pro-environmental behavior, proposing a focus on internal motivators. | Expands behavioral theories by incorporating SME-specific characteristics and their implications for environmental engagement. | How do SMEs' ethical frameworks influence strategic decisions on climate action? What psychological barriers deter pro-environmental decision-making among SME leaders? | [54–58]       |
| Building Resilience and Adapting to Climate Risks                      | Explores systemic and stakeholder-driven approaches for building SMEs' adaptive capacities.                          | Highlights the importance of strategic approaches in navigating climate risks.              | Proposes models showing the shift from reactive to proactive strategies, emphasizing boundary conditions such as industry or size.      | Contributes to resilience theories, integrating dynamic frameworks that align adaptation with strategic objectives.            | What strategies effectively build resilience in diverse institutional contexts? How do stakeholder networks enable or constrain adaptive capacities?                    | [2,11, 59–61] |
| Barriers and Enablers of Energy Efficiency                             | Examines internal and external factors influencing the implementation of environmental strategies.                   | Identifies actionable pathways to mitigate barriers and foster enabling environments.       | Explores SMEs' agency as constrained but innovative actors.                                                                             | Enhances frameworks by showing SMEs as both resource-constrained and proactive agents of change.                               | What barriers hinder SMEs' environmental sustainability efforts? How can enabling ecosystems amplify sustainability drivers?                                            | [62–66]       |
| Building Resilient Enterprises                                         | Investigates vulnerability, collaboration, and organizational capacities affecting resilience to climate challenges. | Positions resilience is critical for long-term SME sustainability.                          | Develops dynamic models linking resilience-building with broader strategic goals.                                                       | Advances theories of resilience as an evolving organizational trait shaped by external and internal factors.                   | How do SMEs balance resilience-building with competing operational demands? What roles do collaborative networks play in mitigating risks?                              | [9,24,74, 88] |
| Institutional and Market Dynamics of Sustainability                    | Focus on how external pressures shape SMEs' sustainable practices.                                                   | Aligns institutional and market dynamics with SME operations.                               | Examines how SMEs navigate conflicting market and institutional demands.                                                                | Integrates SME-specific perspectives into institutional and market theories.                                                   | How do regulatory frameworks impact SMEs' sustainability adoption? What market incentives drive sustainable transformations?                                            | [53, 70–73]   |
| Energy Efficiency and Organizational Strategy                          | Explores adoption patterns for energy-efficient technologies and practices.                                          | Reduces SMEs' energy footprints for sustainability goals.                                   | Links energy efficiency with organizational identity and competitiveness.                                                               | Expands energy efficiency as part of sustainable organizational practices.                                                     | What factors drive or hinder SME adoption of energy efficiency measures? How do stakeholder influences shape energy strategies?                                         | [75,76, 80]   |
| Integrating Environmental and Financial Goals                          | Examine connections between environmental practices and financial performance.                                       | Balances short-term financial needs with long-term sustainability goals.                    | Investigates resource scarcity and sectoral variations in aligning dual objectives.                                                     | Advances in ambidexterity theories in sustainable entrepreneurship.                                                            | What mechanisms align environmental and financial objectives in SMEs? How do leadership influence dual-objective strategies?                                            | [77,79, 87]   |
| Innovations in Circular and Low-Carbon Business Models                 | Focuses on adopting regenerative and decarbonized practices.                                                         | Highlights the transformative potential of circular economy principles.                     | Challenges linear growth assumptions, emphasizing sustainable value creation.                                                           | Integrates circular economy principles into innovation and entrepreneurship theories.                                          | What factors drive innovation in circular models among SMEs? How can SMEs scale such innovations?                                                                       | [14,81, 82]   |

(continued on next page)

Table 9 (continued)

| Cluster                                 | Conceptual Perimeter                                            | Underlying Rationale                                       | Potential Avenues                                                               | Theoretical Value                                                | Possible Research Questions                                                                                                            | Reference |
|-----------------------------------------|-----------------------------------------------------------------|------------------------------------------------------------|---------------------------------------------------------------------------------|------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------|-----------|
| Operationalizing Sustainability in SMEs | Investigates firm-level factors driving sustainable strategies. | Provides actionable strategies tailored to SMEs' contexts. | Explores sustainability integration across different organizational structures. | Embeds sustainability into core operational management theories. | What organizational practices best operate sustainability in SMEs?<br>How do technologies enable SMEs to achieve sustainability goals? | [50,82]   |

#### 4.2. Policy recommendations and implications

To advance sustainability goals, particularly SDG 13 (Climate Action), public policy must address the systemic and structural challenges SMEs face in adopting climate-related strategies. One crucial intervention involves the creation of targeted training and educational initiatives tailored to the unique characteristics of various economic sectors and venture types. These programs should increase awareness of climate change, deepen understanding of its supply chain impacts, and provide actionable insights into corporate strategies for achieving carbon neutrality. Integrating real-world examples from diverse industries can further demonstrate the practical application of these strategies. Partnerships with local chambers of commerce, trade associations, and academic institutions could enhance the effectiveness and reach of these initiatives.

Fiscal measures also play a pivotal role in supporting SMEs' environmental strategies. Subsidies and tax credits designed to offset the costs associated with adopting and maintaining climate-related initiatives can serve as powerful incentives. These financial benefits should be sector-specific to address the varying needs and constraints of different industries. Linking such incentives to local green certifications could enhance awareness and encourage public and private sector alignment toward climate action. For SMEs facing resource constraints, national green credit lines tailored to their specific needs could offer affordable financial solutions,

**Table 10**  
Practical recommendations.

|                                                                                                                                                                                                                                                                                                                                                                                            |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <i>Leadership and strategy.</i>                                                                                                                                                                                                                                                                                                                                                            |
| SMEs' owners and managers should embed sustainability into their business plans, treating it as an opportunity for innovation and competitive advantage.                                                                                                                                                                                                                                   |
| Managers can prioritize small, cost-effective changes like energy audits, waste reduction programs, or switching to renewable energy suppliers to build momentum for larger initiatives.                                                                                                                                                                                                   |
| Regular training for employees on sustainability practices ensures everyone contributes to achieving environmental goals.                                                                                                                                                                                                                                                                  |
| SMEs' owners could introduce sustainability-related compensation packages toward articulating their operational activities with broader environmental goals                                                                                                                                                                                                                                |
| Cultivate a culture that values sustainability by incorporating green practices into the organizational mission and vision.                                                                                                                                                                                                                                                                |
| <i>Operational improvements.</i>                                                                                                                                                                                                                                                                                                                                                           |
| Implement technology-driven tools: SMEs can adopt digital tracking systems to monitor resource usage, identify inefficiencies, and reduce costs. These tools can provide real-time data on energy consumption                                                                                                                                                                              |
| Green supply chain management through collaboration: SMEs can establish operational agreements with suppliers and partners who adhere to environmental standards.                                                                                                                                                                                                                          |
| Transition to circular or sustainable business models: SMEs should adopt practices that emphasize the efficient use of resources throughout the product lifecycle.                                                                                                                                                                                                                         |
| Transitioning to circular models could lower production costs and meet rising consumer demand for eco-friendly products.                                                                                                                                                                                                                                                                   |
| <i>Knowledge sharing and partnerships toward climate resilience.</i>                                                                                                                                                                                                                                                                                                                       |
| Join local business networks and communities focused on sustainability and climate resilience: SMEs can benefit greatly by participating in sustainability-oriented business networks. These networks provide a platform to share best practices; access shared tools, training, and expertise to reduce costs; and collaborate on risk management strategies to build climate resilience. |
| Partner with universities and research institutions: Collaborations with academic institutions offer SMEs low-cost access to expertise and innovative technologies to tackle climate-related challenges.                                                                                                                                                                                   |
| Engage suppliers in climate-related innovation efforts: SMEs should actively collaborate with their supply chain partners on climate-focused innovation, aiming to co-develop greener products and services that meet sustainability standards.                                                                                                                                            |
| <i>Resilience building.</i>                                                                                                                                                                                                                                                                                                                                                                |
| Develop climate action plans: SMEs in high-risk regions should establish comprehensive climate action plans tailored to their specific vulnerabilities. These plans might include floodproofing facilities, installing resilient infrastructure, elevating critical equipment, or diversifying supply chains to reduce dependency on single, risk-prone regions                            |
| Establish an emergency fund: Creating a dedicated climate emergency fund allows businesses to better absorb financial shocks resulting from climate-related disruptions                                                                                                                                                                                                                    |
| Utilize climate-specific insurance products: SMEs should leverage tailored insurance policies designed to cover damages from extreme weather events, such as floods, hurricanes, or droughts                                                                                                                                                                                               |
| <i>Measurement and communication.</i>                                                                                                                                                                                                                                                                                                                                                      |
| Adopt and share simple sustainability metrics: SMEs can use easily understandable metrics, such as energy saved and emissions reduced, to measure and track their sustainability progress.                                                                                                                                                                                                 |
| Share climate-related experiences within the business community: SMEs can actively share their challenges and successes in addressing climate-related risks. This can be done through case studies, blogs, webinars, or community events.                                                                                                                                                  |
| Adopt environmental certifications: Pursuing certifications like ISO 14001 for environmental management systems. This certification reassures stakeholders that the SME is actively minimizing its environmental impact while addressing potential risks.                                                                                                                                  |

enabling them to adopt sustainable practices without jeopardizing financial stability.

Technical assistance programs at the national level could further empower SMEs to develop and implement climate strategies effectively. Training local business advisors in greenhouse gas emission analysis and reduction frameworks would help disseminate knowledge on successful international case studies and key factors for achieving carbon neutrality. Such programs would address knowledge gaps and support SMEs in crafting scalable climate action plans. Public awareness campaigns celebrating successful examples of climate-related practices and strategies could amplify these efforts. For instance, by instituting annual awards or recognitions for SMEs excelling in climate action, policymakers could foster a culture of recognition and incentivize widespread adoption of sustainability-focused practices.

Finally, fostering collaborative networks among SMEs and larger corporations within the same economic sectors could amplify the resources and expertise available for addressing climate challenges. Large corporations could act as hubs of knowledge and resource-sharing, benefiting smaller enterprises through collective efforts. Public policies that incentivize such partnerships—via tax reductions or other benefits—could enhance sector-wide resilience and promote sustainability-driven innovation. These measures not only address immediate climate-related pressures but also contribute to the long-term economic stability and competitiveness of SMEs in a rapidly evolving global landscape.

#### 4.3. Practical recommendations and implications

Table 10 provides a comprehensive framework of actionable insights for SMEs aimed at fostering the adoption of climate-related strategies. The insights are organized into five core areas of execution: leadership and strategy, operational improvements, knowledge sharing and partnerships toward climate resilience, resilience building, and measurement and communication. Besides, executives in SMEs should actively pursue continuous learning to deepen their understanding of climate change and its implications for their businesses. Participation in workshops, seminars, and conferences focused on the intersection of environmental pressures and supply chain resilience can enable leaders to integrate climate-related insights into strategic decision-making. This proactive approach can align financial and non-financial objectives, positioning SMEs as resilient and competitive within their markets.

Strategic planning processes in SMEs should incorporate climate change considerations through comprehensive environmental risk assessments and achievable carbon reduction targets. Exploring innovative solutions for minimizing environmental impacts within supply chains could address key barriers, including financial and technological constraints. Collaboration with sector-specific organizations and alignment with public policy frameworks can further enhance these efforts.

Additionally, SME executives should explore opportunities within carbon markets at both national and regional levels. These markets represent potential income sources that can support broader climate-related strategies. Adopting a phased approach to carbon neutrality—starting with incremental, manageable actions—can build momentum, demonstrate commitment, and establish credibility among stakeholders. Leveraging government programs and technical assistance initiatives can also provide the resources and guidance necessary to overcome operational challenges and regulatory complexities.

By staying informed about policy changes and actively participating in discussions shaping the regulatory landscape, SMEs can anticipate and adapt to evolving environmental requirements. These efforts underscore the critical role of SMEs in addressing climate change while ensuring their own long-term growth and resilience. Promoting sustainability within SMEs not only supports environmental preservation but could also strengthen their economic stability and global competitiveness in an era of heightened environmental accountability.

### 5. Limitations and concluding remarks

Motivated by the increasing academic and societal interest in understanding the role of SMEs in addressing climate change, this study maps the existing literature on climate-related strategies employed by SMEs. Our research responds to two key questions: how has the literature on climate-related strategies and SMEs evolved, and what avenues exist for future research? The findings reveal a notable surge in scientific output between 2020 and 2023, marking the transition of this field into a "Development Phase." Despite this growth, research remains concentrated within a limited number of world regions and institutions, indicating the need for broader geographic and institutional diversification. By examining the intellectual foundations of the field, we identified six research clusters within the bibliographic coupling network and three within the co-citation network, each presenting promising opportunities for further investigation. To advance this area of study, future research must engage deeply with the distinctive institutional, cultural, and economic contexts of different regions, ensuring that public policies designed to support SMEs in mitigating climate change are both contextually relevant and effective.

Our study, however, is not without limitations. First, we restricted our analysis to peer-reviewed articles published in the Web of Science database, prioritizing quality but potentially overlooking insights from alternative sources. Future research could expand the scope by incorporating diverse types of literature, such as books, policy reports, and studies from other databases, even those with varying quality standards. This broader perspective would enrich the understanding of SMEs' climate-related strategies. Furthermore, while our study primarily adopts a descriptive lens to identify trends and gaps, future efforts should strive to go beyond description by synthesizing existing knowledge into a cohesive theoretical framework. Such work could illuminate the decision-making processes and strategic actions of SMEs in response to climate-related challenges, offering a more integrated understanding of this critical and evolving field. Additionally, while we have highlighted theoretical elements that require further exploration, qualitative research with relevant case studies could facilitate an in-depth analysis of our descriptive findings.

While we have provided a comprehensive assessment of the literature, further research could expand the scope of this article in

several ways. First, additional research exploring the core theories, contexts, and variables employed in this literature could offer novel theoretical insights into the field's status [98]. Moreover, longitudinal studies examining the evolution of co-citation and bibliographic coupling networks would allow us to identify inflection points within the intellectual foundations of this research domain. Additionally, investigating the social network and conceptual foundations underlying this literature could further illuminate emerging trends and gaps. [40]. These complementary perspectives would certainly enrich our understanding of the phenomenon.

### CRediT authorship contribution statement

**Julián Andrés Díaz Tautiva:** Writing – review & editing, Writing – original draft, Visualization, Supervision, Software, Resources, Project administration, Methodology, Funding acquisition, Formal analysis, Conceptualization. **Sebastian Barros-Celume:** Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Conceptualization. **Antonio Lecuna:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Funding acquisition, Formal analysis, Conceptualization. **Camila Barragan-Rodriguez:** Writing – review & editing, Writing – original draft, Visualization, Resources, Methodology, Formal analysis, Data curation, Conceptualization.

### Ethics declaration

This study was conducted using publicly available secondary data and did not involve direct interaction with human participants or the collection of primary data. As such, no ethical approval was required. The sources of all secondary data have been duly cited and used in accordance with relevant guidelines and regulations. The authors affirm that the data used were obtained from legitimate and reputable sources, ensuring the integrity and reliability of the research. No conflicts of interest or ethical concerns are associated with the use of this data.

### Data availability statement

The raw data supporting the conclusions of this article is available on the supplementary material.

### Funding

This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors. The APC was funded by Oxford Business College.

### Declaration of competing interest

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

### Acknowledgements

We appreciate the valuable feedback provided by the editorial team and peer reviewers, whose insights have significantly contributed to improving this manuscript. Julián Andrés Díaz Tautiva acknowledges the financial support of Oxford Business College, UK. Camila Barragán-Rodríguez acknowledges the support of the Doctoral Program in Business Economics at Universidad del Desarrollo, Chile. We gratefully acknowledge the valuable support of Prof. Joana Huamán, who served as the climate change expert counterpart in this research.

### Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.heliyon.2025.e43610>.

### Appendix

**Table AI**  
Document-based co-citation network: macro-level network statistics

| Measure        | Value      | Measure              | Value |
|----------------|------------|----------------------|-------|
| Nodes          | 6163.00    | Connectedness        | 0.28  |
| Ties           | 339,886.00 | Fragmentation        | 0.73  |
| Average Degree | 55.15      | Transitivity/Closure | 0.76  |

(continued on next page)

Table AI (continued)

| Measure            | Value  | Measure          | Value |
|--------------------|--------|------------------|-------|
| Indeg H-Index      | 183.00 | Average Distance | 3.20  |
| K-core index       | 254.00 | Prop within 3    | 0.18  |
| Deg Centralization | 0.20   | SD Distance      | 1.12  |
| Out-Centralization | 0.11   | Diameter         | 11.00 |
| In-Centralization  | 0.20   | Breadth          | 0.90  |
| Indeg Correlation  | 0.04   | Compactness      | 0.10  |
| Outdeg Correlation | 0.03   | Density percent  | 0.90  |

Table AII

Document-based bibliographic coupling network: macro-level network statistics

| Measure            | Value  | Measure              | Value |
|--------------------|--------|----------------------|-------|
| Nodes              | 91.00  | Connectedness        | 0.37  |
| Ties               | 794.00 | Fragmentation        | 0.64  |
| Average Degree     | 9.68   | Transitivity/Closure | 0.57  |
| Indeg H-Index      | 16.00  | Average Distance     | 1.90  |
| K-core index       | 18.00  | Prop within 3        | 0.35  |
| Deg Centralization | 0.35   | SD Distance          | 0.79  |
| Out-Centralization | 0.35   | Diameter             | 5.00  |
| In-Centralization  | 0.33   | Breadth              | 0.77  |
| Indeg Correlation  | 0.08   | Compactness          | 0.23  |
| Outdeg Correlation | 0.06   | Density percent      | 12.00 |

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