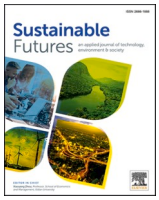
Sustainable Futures 10 (2025) 100922

Contents lists available at ScienceDirect

Sustainable Futures

journal homepage: www.sciencedirect.com/journal/sustainable-futures



Green light for business sustainability: A bibliometric analysis on the integration of green technologies within business strategy

Rocco Pavesi, Luigi Orsi *, Luca Zanderighi

University of Milan, Department of Environmental Science and Policy, via Celoria 2, 20133 Milano, Italy

ARTICLE INFO

Keywords:
Green technology
Business strategy
Business models
Ecological transition
Circular economy

ABSTRACT

The integration of green technologies into business strategies has become crucial for advancing sustainability and fostering innovation. This study aims to explore how sustainability intersects with strategic business practices, offering actionable insights for aligning environmental sustainability with economic growth. Using 922 scientific publications from the Web of Science Core Collection (1990–2023), advanced bibliometric tools—co-citation analysis, bibliographic coupling, and keyword co-occurrence mapping—were employed to identify global research trends, collaborative networks, and thematic developments. These methods facilitated an in-depth exploration of the evolution and impact of green technologies on business strategies over the past three decades. The analysis highlights a sharp increase in publications after 2015, attributed to global initiatives such as the Sustainable Development Goals and the Paris Agreement. Three key research areas were identified: (1) the role of green innovation in sustainability, (2) economic models enabling green practices, and (3) the influence of environmental regulations on business strategies. China has emerged as a global leader in green technology research, fostering extensive international collaborations and contributing significantly to the field's advancement. This study bridges existing gaps by providing actionable insights into how green technologies drive business transformation, offering value to researchers, policymakers, and business leaders seeking to integrate environmental sustainability with economic growth.

1. Introduction

Amidst escalating climate challenges, the imperative for businesses to transition towards sustainable practices has never been more critical. Drawing upon recent studies, such as the exploration of corporate green competitive advantage through green technology adoption and dynamic capabilities [1], the role of corporate social responsibility in fostering green technology innovation [2], and the delineation of emerging green technologies and business models for sustainability [3], our study underscores the profound impact of green technologies on business innovation, offering a compelling narrative for the integration of sustainable processes into core business strategies.

Green technologies and business strategy are crucial components in driving sustainability and innovation within organizations. Green technologies encompass practices such as energy efficiency and sustainable site planning, aimed at reducing environmental impact and fostering economic growth Qiu et al. [4]. Integrating green technologies into business strategies not only promotes environmental sustainability but also influences competitive advantage and value creation [5]. Recent studies have investigated the characteristics and evolution of business models for green buildings, emphasizing the importance of incentives and economics in driving green initiatives [6]. Furthermore, the concept of green business model innovation has gained traction, highlighting the need for dynamic measurement tools to assess green practices in real time [7]. The impact of green innovation on business sustainability has been a focal point, with research indicating the positive correlation between green practices and economic viability, particularly in energy-intensive industries [8]. Additionally, the role of green intellectual capital and absorptive capacity in shaping green business strategies has been explored, emphasizing the importance of structural equation modeling and moderated mediation in understanding these dynamics [3]. The evolving landscape of green strategy research underscores the increasing social awareness and support for sustainable practices, indicating a shift towards greener business models and operations [9]. These recent studies collectively emphasize the significance of integrating green technologies into business strategies to achieve sustainable success, competitive advantage, and environmental responsibility in the modern business environment.

* Corresponding author.
E-mail address: luigi.orsi@unimi.it (L. Orsi).

https://doi.org/10.1016/j.sftr.2025.100922
Received 2 June 2024; Received in revised form 5 February 2025; Accepted 23 June 2025
Available online 23 June 2025

Although bibliometric analyses abound in the fields of environmental science and business management separately, e.g. focusing in the first case on green energy [10,11], as well as green technologies innovation considered under multiple contexts and regulators [12,13], and instead, on the economic side, concentrating on key concepts such as the business model [14] and its implementation of sustainability [15,16], it seems like very few fellow researchers have so far tried to synthesize this whole matter in both a unique and complete academic work, studying and analyzing the interaction between these fields.

This paper distinguishes itself by offering a comprehensive bibliometric analysis that bridges a critical gap in understanding the intersection of sustainability and business strategy through green technologies. While Dewi et al. [17] attempted a bibliometric analysis regarding the relationship between "green technologies" (*et similia*) and "business", their focus remained limited to the analysis and trends of mere keywords, without delving into additional aspects that could have provided a more rounded and complete bibliometric analysis. In contrast, what sets this study apart is its integration of numerical bibliometric measures with qualitative insights, offering a holistic view of how sustainability and business strategy intersect. Moreover, the research extends beyond academic discourse to provide actionable implications for policymakers and business leaders, making it a critical resource for aligning environmental sustainability with economic growth. This multidimensional approach, spanning three decades of research, is unprecedented in the existing literature and fills a critical gap in understanding the transformative role of green technologies in business innovation. Accordingly, this study aims to explore how sustainability intersects with strategic business practices, offering actionable insights for aligning environmental sustainability with economic growth.

In the next section, we detail the methodologies applied for data analysis. Following this, we present our key findings, offering a detailed review of the articles examined, their references, and a visual representation of co-citation, bibliographic coupling, and keyword co-occurrence analyses. Subsequent discussions focus on the significant results of our study. The concluding part highlights the implications of our findings, outlines the limitations of our research, and suggests directions for future investigation into sustainable green technologies in the context of business models and strategies.

2. Theoretical background

The integration of green technologies within business strategies has been extensively analyzed from multiple perspectives, with scholars investigating regulatory influences, economic drivers, and innovation dynamics.

One of the earliest discussions on the intersection of environmental regulation and business competitiveness was introduced by Porter [18], who argued that well-designed environmental policies could enhance innovation and improve firms' long-term competitiveness. This perspective, later refined by Porter and van der Linde [19], challenged the conventional view that environmental regulations impose a cost burden on businesses. Subsequent empirical studies have provided mixed evidence, with some confirming the innovation-stimulating effects of regulation [20] while others highlight sectoral differences in regulatory impact [21]. The role of green innovation in shaping business performance has been another focal point of research. Rennings [22] introduced the concept of eco-innovation, distinguishing between regulatory-driven and market-driven sustainability transformations. Later studies, such as Horbach et al. [23], emphasized the influence of firm-specific capabilities in successfully integrating green technologies into business models. More recently, research has examined the strategic implications of circular economy principles, demonstrating that companies adopting resource-efficient practices often achieve cost reductions and competitive advantages [24].

Economic and policy drivers play a crucial role in facilitating the adoption of green technologies. Market-based incentives, including carbon pricing and green subsidies, have been widely studied for their effectiveness in promoting sustainable investments [25]. Public-private partnerships have also emerged as a critical mechanism in advancing green R&D and scaling up sustainable innovations [26]. However, several studies highlight persistent barriers to green technology adoption, including high initial costs, consumer resistance, and regulatory uncertainty [27].

Another emerging area of interest is the role of knowledge management in green business models. Research on green intellectual capital has demonstrated how firms leveraging sustainability-oriented knowledge assets tend to outperform competitors in innovation efficiency and environmental impact mitigation [28].

The concept of absorptive capacity, originally introduced by Cohen and Levinthal [29], has also been applied to sustainability research, emphasizing how firms' ability to integrate external green knowledge directly influences their technological transformation [30]. As the digital economy advances, scholars have begun exploring the interplay between artificial intelligence, big data, and green technology adoption, identifying new frontiers for sustainable business strategy [31]. From a business management perspective, strategic tools have also evolved to accommodate sustainability-driven innovation. Zott and Amit [32] laid the foundation for business model theory, focusing on value creation through inter-firm networks and strategic resources. Over time, business model frameworks have expaded to incorporate environmental and social dimensions, with scholars developing approaches like the Triple Layered Business Model Canvas [33], the Eco-Canvas [34], and the Circular Triple Layered Business Model Canvas [35]. These tools integrate economic, environmental, and social considerations, allowing firms to design more sustainable business models. The shift towards such frameworks reflects the growing recognition that long-term competitiveness increasingly depends on sustainable value creation rather than short-term financial gains.

In summary, the existing literature highlights a dynamic and evolving relationship between green technologies and business strategy, shaped by regulatory frameworks, economic incentives, and organizational capabilities. However, despite the extensive body of research, a comprehensive, data-driven perspective on how these elements interact over time remains limited.

This study builds upon these foundations by offering a bibliometric analysis that systematically maps global research trends, thematic developments, and collaborative networks within this interdisciplinary field. By leveraging bibliometric techniques, this study systematically maps global research trends, thematic developments, and collaborative networks within this interdisciplinary field. This approach allows for the identification of key knowledge clusters, research gaps, and emerging trajectories, offering both scholars and practitioners a structured understanding of how green technologies integrate into business strategies over time.

3. Methodology

3.1. Search strategy

Selecting an appropriate database is crucial for conducting dependable bibliographic analysis. Clarivate Web of Science (WoS), considered the "gold standard", has been widely used for evaluating academic performance and ranking universities [36]. Elsevier's Scopus and Google Scholar (GS) have gained popularity as alternatives, with Scopus being a well-established competitor since 2004 (ibid.). WoS, nevertheless, has been widely recognized as a superior tool for bibliometric analysis compared to Scopus and Google Scholar for several reasons: it is the oldest scholarly database [37], with >74.8 million records and 1.5 billion references in 254 subject disciplines [38], and it results to be more precise in uniforming references from all the documents present in it with respect to other databases [39]. In addition to that, the citation

analysis offered by Web of Science appears to have superior visuals and more in-depth details compared to that of Scopus [40]. Lastly, WoS has a more rigorous selection process for its indexed journals, ensuring the quality of the publications included in the analysis [41]. In contrast, Google Scholar, while having a broader coverage, cannot filter out low-quality publications and grey literature, which can potentially skew the results of a bibliometric analysis [42]. Therefore, for a more comprehensive, accurate, and quality-controlled bibliometric analysis, WoS was eventually adopted.

To maintain the quality of the publication sample, articles were retrieved from the Wos "Core Collection" spanning the period 1990 to 2023. WoS has been widely employed in scientometrics research, and the primary bibliometric analysis software is designed for its use (e.g. [43,44]). The chosen time frame for this research, traversing from the 1990s to the present, is justified by the emergence of green growth and the convergence between green technologies and businesses during this period. As Hart [45] emphasizes, the 1990s marked the beginning of businesses incorporating sustainability into their strategies, moving beyond mere compliance, and adopting innovative practices for long-term sustainability. Examining this period allows the research to capture the critical juncture at which the prioritization of green growth and the evolution of green technologies unfolded, offering valuable insights into the dynamics and impact of this transformative era.

The keywords used for the search through the WoS "Core Collection" were (*"green* tech*" OR "clean* tech*" OR "sustain* tech*") AND ("strateg*" OR "business* model*")* in the topic (title, abstract, and keywords). The selected keywords were deliberate in their choice, aiming to encompass the broader landscape of emerging sustainable technologies. On the technology side, by incorporating variations of these terms (green, clean, and sustainable), the search sought to encompass a comprehensive body of literature, since, as pointed out by Ebrahim [46], while different terminology is utilized, each refers to innovative technological solutions for environmental issues. Furthermore, the keywords were specifically chosen to link the technology side with the business side of green technologies: the choice of "business model" and "strategy" as keywords for our analysis stems from the understanding that, as Mignon & Bankel [47] highlighted, integrating sustainable technologies into businesses is fundamentally a strategic innovation challenge. This approach acknowledges that achieving sustainability is not just about adopting new technologies but about redefining how businesses operate and compete. The interrelation between business models and strategic planning is crucial for firms aiming to embed sustainability into their core operations. Eventually, this focused approach facilitated the retrieval of pertinent academic literature that focuses on the interconnection between sustainable technologies, business models, and strategies, thereby furnishing valuable insights for scholarly inquiry. To strengthen a specific emphasis, the research was limited to the "Web of Science Categories" of "Economics", "Management", "Business", and "Environmental Sciences", as concentrating the search within these domains ensures a targeted exploration of scholarly literature directly relevant to the scope of the study. Finally, as already mentioned, the selected time frame ranged from 01 to 01–1990 to 31–12–2023, resulting in a final sample of 951 papers, authored by 3053 distinct scholars. These papers were disseminated across a broad array of 250 unique academic journals or sources. For co-citation analysis, it is critical to underscore that the referenced literature is not strictly confined to the time frame of 1990–2023 but can draw from publications of any year. The chosen sample only includes academic papers that are written in English, as it is often argued that focusing solely on English-written papers is crucial for the effectiveness of bibliometric analysis [48–50].

3.2. Data analysis

In conducting our thorough bibliometric study, the utilization of R and RStudio proved to be crucial. R, a widely used software environment for statistical computing and graphics, provided a robust set of techniques and graphical methods essential for data analysis and visualization [51]. Complementing R, RStudio served as an integrated development environment (IDE) that enhanced the user experience by offering features like syntax highlighting, debugging tools, and workspace management, thereby streamlining the coding process and improving workflow efficiency [39]. For the specific needs of the bibliometric study, the researchers employed the Bibliometrix R package within RStudio. Bibliometrix, designed for comprehensive science mapping analysis, equipped the researchers with a suite of functions tailored for quantitatively analyzing bibliometric data [52]. This integration of R's computational capabilities and RStudio's user-friendly interface facilitated the efficient execution of the bibliometric study, enabling in-depth analysis and visualization of the data. By leveraging these tools within the R environment, the researchers were able to examine the intricacies of bibliometric analysis, benefiting from the advanced statistical computing features of R and the enhanced coding environment provided by RStudio. This approach not only streamlined the data manipulation and calculation processes but also facilitated the graphical representation of the findings, contributing to a more thorough and insightful bibliometric study.

A notable enhancement in our analysis process was facilitated by Biblioshiny, a user-friendly web interface for the Bibliometrix R-package. This tool significantly streamlined the data cleaning phase, allowing for an efficient exclusion of documents that did not meet our quality criteria. Specifically, Biblioshiny enabled the removal of 26 documents due to missing DOIs and an additional 3 for lack of abstracts. This cleansing ensured the final dataset, now composed of 922 papers, was robust and reliable for further analysis [39]. Beyond data cleaning, Biblioshiny was extensively used for the descriptive analysis of the sample, providing insights into publication trends, most prolific authors, institutions, and countries, thereby setting a solid foundation for the detailed examination of the bibliometric landscape.

Simultaneously, VOSviewer plays a crucial role in the construction and visualization of bibliometric maps. This software specializes in the visualization of bibliometric networks, and clustering papers based on measures such as bibliographic coupling, co-citation counts, and keyword co-occurrence. These methods are in line with the established methodology for bibliometric analysis and offer a deeper understanding of the thematic structures within the dataset [53]. The use of VOSviewer for the creation and visualization of bibliographic coupling, co-citation, and keyword co-occurrence networks further enriches our study by illuminating the interconnectedness and thematic focus of the research landscape.

3.3. Method of analysis

Bibliometric tools offer a quantitative analysis of academic literature, presenting a map of discipline-specific trends and relationships [54,55]. Three main techniques are used: direct citations, co-citation analysis, and bibliographic coupling, each offering different views of document relationships [53,56]. Bibliographic coupling and co-citation analysis, which focus on joint citations and commonly cited references respectively, are believed to be more accurate than direct citations [57]. While co-citation analysis helps to identify the discipline's key concepts, methods, and experiments [58], bibliographic coupling is increasingly used for its utility in studying emerging fields [53,59]. In contrast to co-citation's retrospective view, bibliographic coupling offers a more forward-looking perspective. The study also incorporated a co-occurrence analysis of keywords, as described by Sedighi [60], to better understand the thematic structure of a research field and identify interconnected concepts or trends [61]. Fig. 1 provides a graphical representation and summary of the methodology and criteria used in the preparation of the study.

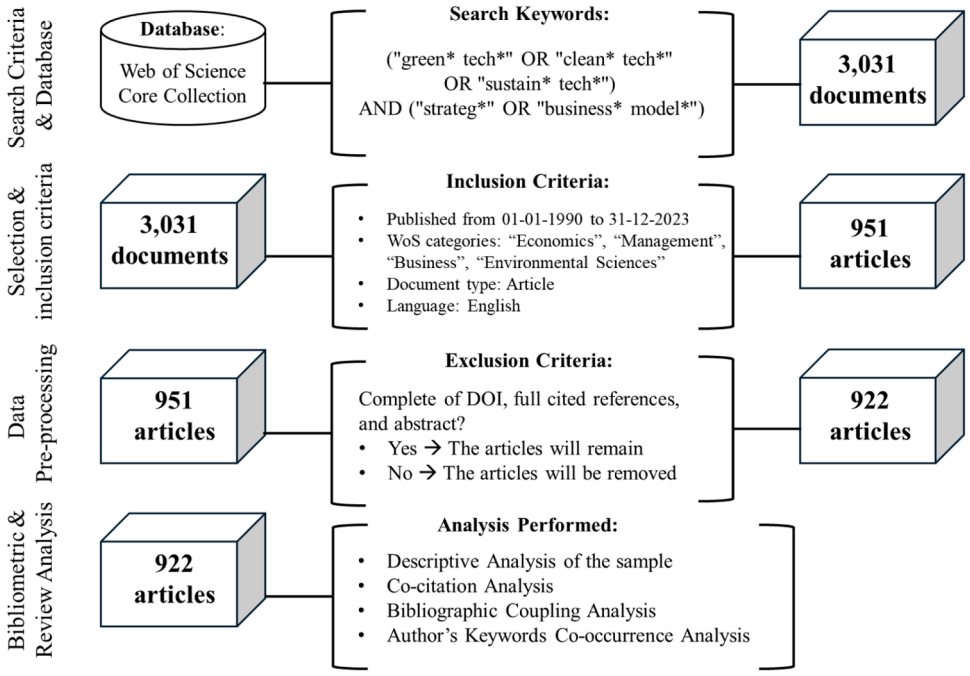


Fig. 1. Methodological flowchart.

4. Results

4.1. Descriptive analysis of the sample

The provided data indicates a growing trend in the number of publications over the years on the topics of green, clean, and sustainable technologies with business models or strategies. Fig. 2 elucidates a notable uptick in interest beginning between 2015 and 2017, coinciding with the United Nations' ratification of the 2030 Agenda and its accompanying Sustainable Development Goals in 2015, as well as the enactment of the Paris Agreement in 2016. However, it is post-2018 that the publication trajectory markedly steepens, with each successive year outpacing the last, culminating in a zenith of 257 papers in 2023. The steep increase in the later years might be attributed to the intersection of multiple global developments: the 2030 Agenda invigorated the integration of business practices with sustainable development objectives [62]; and the Paris Agreement reinforced the urgency of decarbonization and climate action [63]; most relevantly, eventually, the COVID-19 pandemic prompted a re-evaluation of global economic resilience and sustainability [64]; Together, these factors have not only elevated the discourse on environmental and social responsibility but have also necessitated a profound scholarly focus on how green technologies can be woven into the fabric of business strategy, reflecting a paradigm shift towards prioritizing sustainability in the face of rapid environmental changes and societal expectations. Given this trend, we can anticipate that the focus on the intersection of sustainability and business strategy will continue to increase, driving further research and publications in the years to come.

Table 1, on the other hand, displays the top 10 journals for the papers considered as the sample in this analysis. The landscape of academic journals pertaining to the integration of green technologies in business strategies showcases a remarkable scenario of interdisciplinary focus, underlined by a collective high-impact scholarly contribution. The Western-centrism of this ranking, merely based on the country of origin

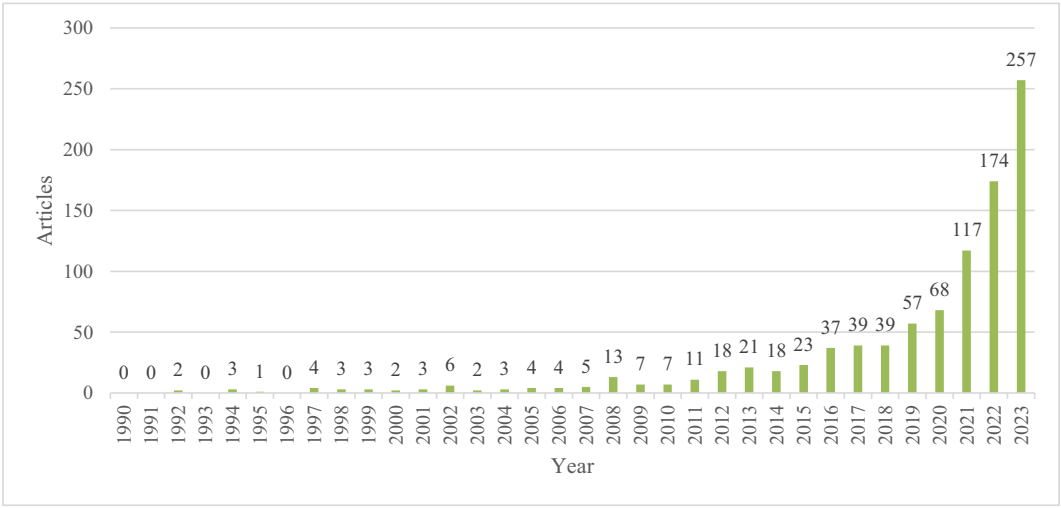


Fig. 2. Annual Scientific Production.

Table 1
List of the top 10 Journals.

Journals	Country	Publisher	IF 2022	Articles
Sustainability	CH	MDPI	3.9	138
Journal of Cleaner Production	NL	Elsevier	11.1	131
Environmental Science and Pollution Research	USA	Springer	5.8	74
Journal of Environmental Management	NL	Elsevier	8.7	24
Technological Forecasting and Social Change	NL	Elsevier	12	22
Business Strategy and The Environment	USA	Wiley	14.88	21
Frontiers in Environmental Science	CH	Frontiers	10.3	21
Science of the Total Environment	NL	Elsevier	9.8	19
Environment Development and Sustainability	USA	Springer	4.9	18
International Journal of Environmental Research and Public Health	CH	MDPI	4.53	17

of the publisher, should not overcome the high internationality profile that characterizes each one of them. The diverse focus areas of these journals reflect the multifaceted nature of sustainability research, pointing to the importance of a holistic approach that integrates environmental, technological, social, and health perspectives. By taking a deeper look at these journals' aims and scopes, it is then possible to identify three main clusters:

1) Technical and Applied Sciences: Journals like "Sustainability", "Science of the Total Environment", and "Journal of Cleaner Production" focus on technical solutions and innovations in sustainability;
2) Environmental and Ecological Research: Journals such as "Environmental Science and Pollution Research" and "Frontiers in Environmental Science" emphasize ecological research and the study of environmental changes;
3) Business and Environmental Strategies: journals like "Journal of Environmental Management", "Environment Development and Sustainabilty", and "Business Strategy and the Environment" focus on the implementation of environmental sustainability practices, strategies, and policies within business operations and management;

Distinguished within this top ten list, two journals—"Technological Forecasting and Social Change" and the "International Journal of Environmental Research and Public Health", ranked 5th and 10th respectively—stand out for adding remarkable depth of interdisciplinarity and diversity to the field. As the former is dedicated to exploring the interrelations between social, environmental, and technological factors through the lens of technological forecasting and future studies, the latter is a transdisciplinary journal that focuses on health promotion and disease prevention within the context of environmental research. Their prominent standings, despite their distinct focuses, underscore their critical contributions and relevance to the field, particularly for what concerns the unique contribution of "Technological Forecasting and Social Change" lies in its forward-looking perspective, focusing on predicting and planning for future technological developments and their societal and environmental implications. This approach is crucial for integrating green technologies into business strategies, as it emphasises foresight and the anticipation of future trends.

Citations are often employed as a measure of the impact of works within a particular research domain. Table 2 provides a list of the ten most cited papers of the sample within the sample itself, ranked by their local citation count. The value of global citations, i.e. citations from the whole academic world, are reported as a contextual reference. The collection of the most cited papers on the integration of green technologies within business strategy spans a rich array of insights, theoretical frameworks, and empirical analyses, published across prestigious journals. The most recurring one is the "Journal of Cleaner Production", a leading international journal that focuses on sustainable development and environmental management practices. Nevertheless, it's important to emphasise that the top and bottom positions in this ranking are held by prestigious journals with a focus on business and strategy, namely "Technology Analysis & Strategic Management" and "Harvard Business Review." This underscores the critical role of strategic considerations in the successful integration of green technologies into business operations. By analysing these papers, it is possible to identify three main recurring thematics. The first one is the foundational theme that emerges through the theoretical and strategic frameworks proposed in seminal works by Kemp et al. [65], Hart [45], and Bohnsack et al. [66]. Kemp's introduction of strategic niche management offers a nuanced approach to managing the transitions towards sustainable technologies, highlighting the importance of protective spaces for innovation. Hart expands on this by delineating a comprehensive framework for sustainable

Table 2
List of the top 10 cited papers.

Title	Author(s)	Journal	Year	Local Citations	Global Citations
Regime shifts to sustainability through processes of niche formation: The approach of strategic niche management	Kemp, R., Schot, J. & Hoogma, R.	Technology Analysis & Strategic Management	1998	18	1543
Optimal strategy for enterprises' green technology innovation from the perspective of political competition	Deng, Y., You, D., & Wang, J.	Journal of Cleaner Production	2019	15	74
Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: Does service capability matter?	Fernando, Y., Chiappetta Jabbour, C. J., & Wah, W.	Resources, Conservation and Recycling	2019	14	317
Efficiency evaluation of green technology innovation of China's strategic emerging industries: An empirical analysis based on Malmquist-data envelopment analysis index	Luo, Q., Miao, C., Sun, L., Meng, X., & Duan, M.	Journal of Cleaner Production	2019	12	147
Business models for sustainable technologies: Exploring business model evolution in the case of electric vehicles	Bohnsack, R., Pinkse, J., & Kolk, A.	Research Policy	2014	11	329
General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007	Montalvo, C.	Journal of Cleaner Production	2007	10	165
Ecological-economic efficiency evaluation of green technology innovation in strategic emerging industries based on entropy weighted TOPSIS method	Sun, L., Miao, C., & Yang, L.	Ecological Indicators	2017	10	196
A sustainable production-inventory model for a controllable carbon emissions rate under shortages	Mishra, U., Wu, J., & Sarkar, B.	Journal of Cleaner Production	2020	10	135
Top management team faultlines, green technology innovation and firm financial performance	Ma, Y., Zhang, Q., & Yin, Q.	Journal of Environmental Management	2021	10	75
Beyond Greening: Strategies for a Sustainable World	Hart, S. L.	Harvard Business Review	1997	9	788

development, charting the stages of environmental strategy, and pinpointing business opportunities that arise from sustainable practices. Meanwhile, Bobhnsack concentrates on the evolution of business models within the electric vehicle sector, showcasing how path-dependent behaviors of firms significantly shape the trajectory of sustainable technology integration. If this first one focuses on strategy, the papers by Deng et al. [67], Mishra et al. [68], and Montalvo [69] go deep into the nuanced relationship between policy, governance, and the economic ramifications of embracing green technologies.

Deng's work utilizes game theory to dissect how political competition influences strategies for green technology innovation, presenting a unique intersection of politics and business strategy. Mishra's study sheds light on the effectiveness of carbon tax and cap policies, underlining their significant role in steering investments toward green technologies and reducing carbon emissions. Montalvo provides a comprehensive survey on the myriad factors that affect the adoption and diffusion of cleaner technologies, with a special focus on policy and its implications for economic growth. Eventually, the papers from Fernando et al. [70], Luo et al. [71], Sun et al. [72], and Ma et al. [73] all collectively illustrate the importance of innovation in driving market dynamics and enhancing sustainability, explaining their high citation rates as essential resources for both researchers and practitioners aiming to leverage green technologies for sustainable business outcomes, particularly in Fernando's research which illuminates how service innovation serves as a crucial mediator between eco-innovation and business sustainability, suggesting that the integration of environmental considerations into service offerings can enhance corporate sustainability.

In concluding our descriptive analysis, a nuanced examination of the geographical spread within this rapidly evolving research domain reveals significant insights. The country collaboration map presented in Fig. 3 delineates the extent of scholarly interactions across nations. Countries are shaded in progressively darker tones of blue to denote the frequency of their international collaborations, connected by red lines. A striking observation from this visual representation is the prominent position of China, indicated by its dark blue hue and extensive network of red lines signifying numerous partnerships. Notably, while a global discourse is evident, with participation from the majority of the world, certain regions such as South America, Greenland, some Eastern countries, and large swathes of the African continent, appear less engaged. This suggests a concentration of academic efforts and partnerships within specific areas of the world, as corroborated by the bilateral interactions concerning the integration of green technologies in business strategy. Predominantly, China emerges as a central node in this network, engaging with a diverse set of countries including the UK, USA, India, Korea, Pakistan, Australia, Malaysia, and Denmark. It is particularly noteworthy that China's sphere of influence extends beyond the traditional Western academic powerhouses, resonating also with Eastern nations: collaboration among such countries extends beyond simple geographic closeness, as it is underpinned by a complex dynamic of factors including shared economic goals, strategic regional initiatives like the "Belt and Road", similar environmental challenges, and the pursuit of sustainable development. Coherent policy directives among these nations further catalyze partnerships, indicating a collective prioritization of green technology within their economic strategies. Such partnerships suggest a deliberate regional approach to leverage combined expertise and innovation in advancing sustainable practices. This trend is emphatically reflected in the trajectory of research outputs as illustrated in Fig. 4. Post-2020, China has witnessed an exponential surge in scholarly publications within this field, a testament to its central role and a clear indicator of its ascendance to a position of global leadership in green technology research, well aligned with its strategic objectives as outlined in the nation's 14th Five-Year Plan. Such a meteoric rise in academic productivity is a sign of a shifting paradigm, where China is not only actively shaping the field but also setting the pace and direction for future developments.

4.2. The co-citation network analysis

As previously discussed, the utilization of co-citations, which refers to the pairing of two publications that are both cited by another paper and listed in the paper's references [74], can contribute to the comprehension of the fundamental concepts, methodologies, or the current state of advancement in a particular field. The examination of co-citations involves identifying the occurrences of joint references, in this work, within the collection of papers relevant to green technologies and business strategies, thereby enabling the identification and categorization of documents that may not have a direct connection to the

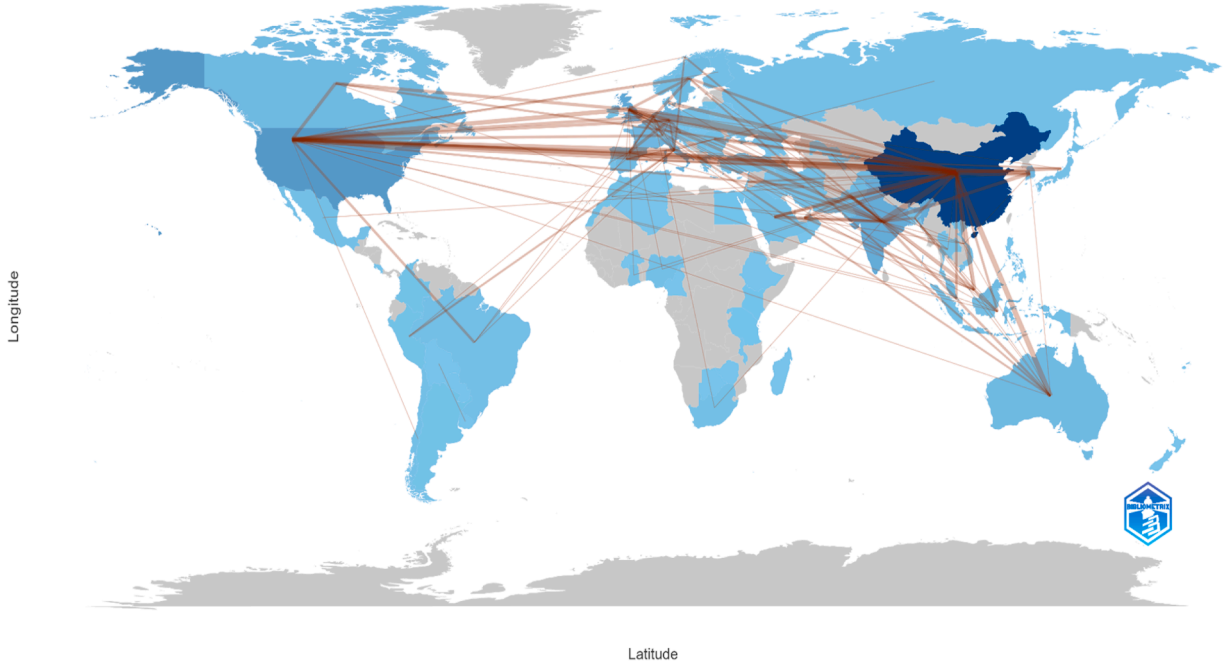


Fig. 3. Country Collaboration Map.

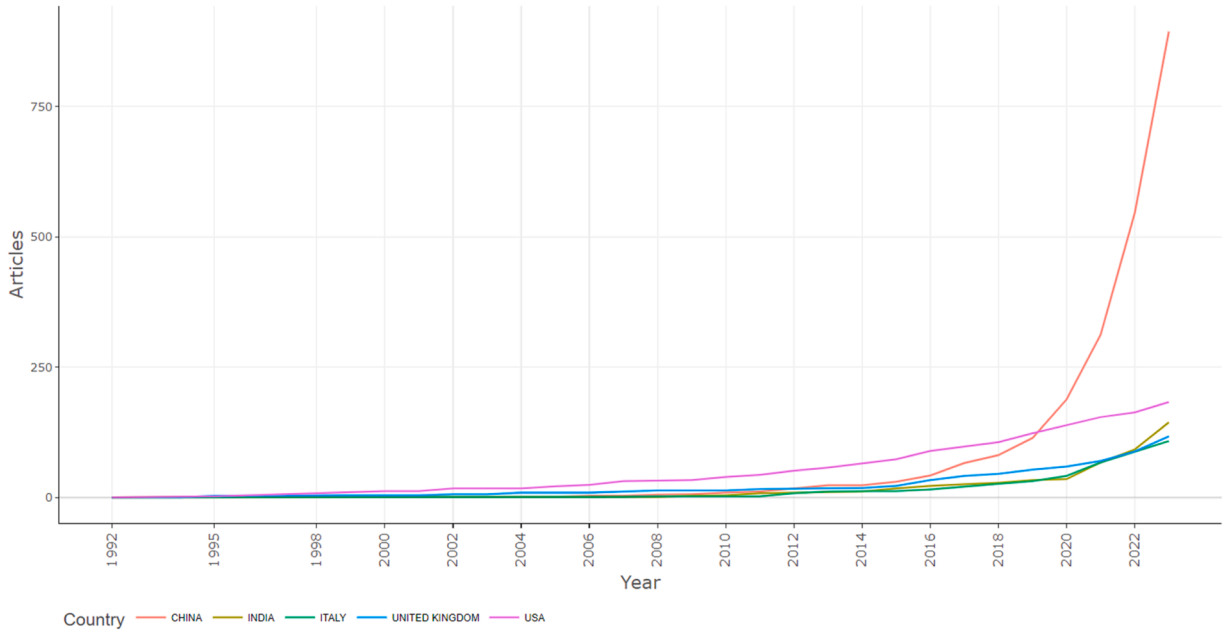


Fig. 4. Top countries' production over time.

field. This approach adopts a retrospective perspective and is commonly employed to ascertain the seminal works within a specific research domain. This study performs a document co-citation analysis of 51,383 valid references that have been cited by the 922 publications in this sample. Given the substantial number of references connected to the concept of the integration of green technologies within business strategies, the objective was to enhance the network's interpretability and concentrate on the core publications. Thus, to achieve a sample consisting of 138 valid references, we established a threshold that only includes papers with a minimum of 10 citations. This threshold represents an equitable citation count in consideration of the "greenness" of this subject matter and symbolises a just equilibrium between the contraction of information attributable to an excessive threshold. After further refinements of the sample, including the exclusion of 3 cited references for lack of data, and of 1 other for not having any connections within the network, the final sample consisted of 134 valid cited references.

The analysis of the co-citation network reveals the structural properties of both the network and the clusters. At the structural network level, the key network measures are density and modularity. Density is calculated as the ratio of existing links to all possible links within a subgroup, therefore, a maximum density is obtained when all nodes in a subgroup are linked to all other nodes in that group. As a bibliometric indicator, density reflects the extent to which various streams within a subfield of research pursue their agendas on common grounds. The network has a density of 0.27, which indicates that the network is moderately dense, with present connections among the documents [59]. Determined by using an algorithm for community detection, the modularity index measures how well the network can be clustered into groups [75]. Within the network, the analysis identifies five main clusters: the modularity value obtained for the network stands at 0.46, signifying considerable interlinkages among all the documents included in the analysis [76]. This value also underscores the substantial overlap among the five identified clusters. The moderate modularity score attests to the presence of noteworthy interconnectedness across all document clusters, rather than sharply distinct divisions.

Table 3 enumerates the association strength, label, size, and average publication year for each document cluster. Regarding the association strength, it is used for normalising the strength of the links between items; apart from a multiplicative constant, this method is identical to Eq. (6) in Van Eck and Waltman [77]. Subsequently, a comprehensive qualitative assessment of the content within these four distinct clusters is presented. To illustrate the evolution of the understudied research field, clusters are arranged chronologically, guided by the average publication year of the documents within each cluster. For length restrictions, only the first author will be reported.

4.2.1. *Co-citation cluster 1: sustainable supply chains*

This collection of studies converges on the critical examination of how collaborative strategies and innovative contract designs can promote environmental sustainability within supply chains, underscoring the complexity of aligning economic incentives with environmental objectives through strategic supply chain management. Krass et al. [78] sets a foundational context by investigating the role of environmental taxes, fixed cost subsidies, and consumer rebates in motivating firms towards green technologies, highlighting the significant influence of regulatory policies on corporate sustainability decisions. This backdrop is crucial for understanding the dynamics that drive supply chain entities towards collaborative and innovative contractual arrangements. For instance, Hong & Guo [79] and Ghosh & Shah [80] explore the nuances of contract designs, such as green-marketing cost-sharing and two-part tariff contracts, and their potential to drive or deter the adoption of environmentally friendly practices. These studies highlight the centric role of contractual agreements in fostering cooperation among supply chain partners, thereby enhancing the environmental performance of the entire chain. Moreover, the interaction between consumer demand for green products and the effectiveness of supply chain coordination emerges as a significant theme. Liu et al. [81] and Ghosh & Shaha [80] provide insights into how increased consumer environmental consciousness not only influences the strategic decisions of individual firms but also catalyzes collaboration between manufacturers and retailers. This consumer-driven demand acts as a linchpin in encouraging supply chain entities to adopt greener operations, underscoring the importance of understanding market dynamics in the design of environmental strategies. The emphasis on collaboration extends to policy implications, where the interchange between governmental incentives and private sector strategies is scrutinized. Studies like those by Bi et al. [82] and Cohen et al. [83] investigate how government subsidies and regulations can be structured to complement supply chain initiatives, suggesting a synergistic approach to achieving sustainability goals.

Table 3
Overview of co-citation clusters.

Documents in cluster and association strength (in parentheses)	Label	Description	Cluster number	Size	Year (avg.)
Krass (2013), (127); Xu (2017), (73); Drake (2016), (70); Hong (2019), (64); Liu (2012), (64); Ghosh (2015), (63); Bi (2017), (60); Cohen (2016), (60); Ghosh (2015), (58); Benjaafar (2013), (56); Swami (2013), (56); Yang (2021), (56); Dong (2016), (53); Yalabik (2011), (51); Chen (2019), (48); Bian (2020), (47); Chen (2001), (47); Xu (2016), (44); Zhu (2017), (42); Toptal (2014), (41); Yang (2018), (34); Mishra (2020), (33)	Sustainable Supply Chains	Cluster 1 explores the impact of collaborative strategies and contract designs on enhancing environmental sustainability within green supply chains.	1	22	2015
Porter (1995), (305); Rennings (2000), (180); Xie (2019), (144); Du (2021), (134); Lv (2021), (115); Baron (1986), (109); Jaffe (1997), (108); Acemoglu (2012), (104); Cai (2020), (103); Horbach (2008), (93); Fernando (2019), (84); Du (2019), (80); Li (2017), (80); Zhang (2019), (77); Ambec (2013), (75); Porter (1991), (75); Singh (2020), (75); Horbach (2012), (72); Rubashkina (2015), (72); Jaffe (2005), (71); Popp (2006), (71); Deng (2019), (69); De Marchi (2012), (67); Cai (2018), (65); Kraus (2020), (62); Brunnermeier (2003), (60); Kunapatarawong (2016), (60); Song (2020), (58); Du (2019), (57); Miao (2017), (57); Ma (2021), (53); Sun (2017), (51); Xu (2021), (51); Hambrick (1984), (50); Bai (2019), (48); Yu (2021), (48); Jaffe (2002), (46); Acemoglu (2016), (45); Li (2018), (45); Yuan (2018), (45); Luo (2021), (42); Luo (2019), (41); Wang (2019), (40); Braun (1994), (38); Wang (2021), (36); Arellano (1991), (30); Wu (2020), (27); Cao (2021), (26); Charnes (1978), (14); Field (2014), (11); Grossman (1995), (5)	Porter's Hypothesis	Cluster 2 investigates the dynamic relationship between environmental regulation, eco-innovation, and economic performance, highlighting the critical role of policy in fostering sustainable development and green technology advancements.	2	51	2012
Boons (2013), (108); Cohen (1990), (101); Hockerts (2010), (99); Schaltegger (2012), (89); Eisenhardt (1989), (87); Teece (1986), (84); Bocken (2014), (83); Teece (2010), (82); Geels (2002), (78); Bohnsack (2014), (77); Kemp (1998), (75); Schaltegger (2016), (74); Stubbs (2008), (74); Boons (2013), (72); Chesbrough (2002), (71); Eisenhardt (2007), (70); Geels (2007), (70); Zott (2011), (70); Christensen (2013), (65); Chesbrough (2010), (61); Nelson (1982), (53); Gioia (2013), (51); Hekkert (2007), (50); Markard (2012), (50); Schot (2008), (50); Bergek (2008), (49); Unruh (2000), (41); Cohen (2007), (35); Stern (2008), (8); Pesaran (2001), (4); Hoel (2010), (3)	Strategic Green Integration	Cluster 3 studies the interplay between business model innovation, organizational absorptive capacity, and strategic management for sustainable technological transitions.	3	31	2006
Hart (1995), (186); Chen (2006), (144); Sharma (1998), (137); Barney (1991), (136); Fornell (1981), (122); Porter (1995), (109); Berrone (2013), (103); Russo (1997), (100); Podsakoff (2003), (98); Teece (1997), (98); Chen (2008), (89); Aragón-Correa (2003), (83); Klassen (1999), (82); Shrivastava (1995), (82); Hair (2010), (81); Podsakoff (1986), (74); Teece (2007), (74); Chiou (2011), (72); Hart (2011), (71); Schiederig (2012), (69); Wernerfelt (1984), (68); Hart (2003), (67); Pujari (2006), (64); Dangelico (2016), (60); Armstrong (1977), (52); Hart (1996), (51); Dimaggio (2000), (42); Montalvo (2007), (41); Suchman (1995), (32); Ajzen (1991), (22)	Holistic Sustainability	Cluster 4 highlights the shift in strategic management from treating environmental sustainability as an external factor to a core component of competitive advantage.	4	30	2000

Notes: The table reported only the first author's name, the year of documents and the number for citations due to spatial constraints. For the same reasons these authors have been not included in the references.

4.2.2. Co-citation cluster 2: porter's hypothesis

Porter & Van der Linde [19] lay the foundation by challenging the presumed trade-off between environmental regulation and competitiveness, advocating for environmental standards that spur innovation and enhance resource productivity. This premise is echoed and expanded upon by Rennings [22], who introduces eco-innovation as a multifaceted concept encompassing technological, social, and institutional changes, driven in part by regulatory mechanisms. The notion of regulatory influence is further substantiated by Xie et al. [84] and Du et al. [85], who explore the positive dynamics between green technology innovation and financial performance within firms, highlighting the role of environmental regulation as a significant driver. Moreover, publications in this cluster highlight the critical role of financial and institutional frameworks in supporting eco-innovation. Lv et al. [86] identify the nuanced effects of financial development on green technology innovation, emphasizing the mediating and moderating roles of environmental regulation and innovation output. This complexity is further illustrated by Cai et al. [87], who observes the significant incentive effect of direct environmental regulations on green technology innovations within heavily polluting industries, suggesting a nuanced interaction between policy, ownership, and industry type. Du et al. [88] fits here by expanding the discussion on how the impact of green technology innovations on CO2 emissions varies across economies with different income levels, adding a crucial layer to understanding the environmental and economic interplay of green technology. The empirical investigations by Jaffe & Palmer [89] and Horbach [90] provide evidence supporting the positive impact of environmental regulation on R&D expenditures and the encouragement of environmental innovations, aligning with the Porter hypothesis. Acemoglu et al. [91] introduce a theoretical model to demonstrate how directed technical change towards "clean" inputs, facilitated by policy interventions, can achieve sustainable growth, which is a critical consideration for achieving long-term environmental and economic objectives.

4.2.3. Co-citation cluster 3: strategic green integration

A common theme across this third cluster is the recognition of the complexity and diverse nature of driving sustainable innovation within and across industries. Boons & Lüdeke-Freund [92] and Bocken et al. [93] both emphasize the necessity of integrating sustainable business models that encompass a triple-bottom-line approach, addressing environmental, social, and economic dimensions. This perspective is reinforced by Hockerts & Wüstenhagen [94] who discuss the interaction between new entrants and incumbents in fostering industry-wide sustainability transformation, highlighting the roles of both 'Emerging Davids' and 'Greening Goliaths'. Cohen & Levinthal [29] introduce the concept of absorptive capacity, which is critical for firms' innovative capabilities and their ability to adapt and apply new, external information for commercial ends. This idea of absorptive capacity is echoed in the discussions by Schaltegger et al. [95] and Teece [96] about the importance of business model innovation and the architecture of value creation, delivery, and capture in supporting sustainable practices and innovations. The challenge of transitioning to sustainable technologies and overcoming market penetration barriers is a focal point in the work by Bohnsack et al. [66] and Kemp et al. [65], who both address the need for strategic approaches in managing technological regimes and niches to expedite sustainable development. Similarly, Hekkert et al. [97] propose a framework focusing on the functions of innovation systems to better understand and facilitate technological change towards sustainability.

4.2.4. Co-citation cluster 4: holistic sustainability

Hart [98] lays the foundational premise by introducing a natural-resource-based view of the firm, emphasizing pollution prevention, product stewardship, and sustainable development as key strategies for leveraging the natural environment for competitive advantage. This view is echoed by Chen et al. [99], who find a positive correlation between green innovation (both product and process) and competitive advantage, arguing for the strategic importance of green innovation investment. Sharma & Vredenburg [100] extend this discussion to the impact of green marketing orientations on SME performance, highlighting the importance of both tactical and strategic approaches to green marketing in enhancing firm and environmental performance. Barney [101] and Teece et al. [102] contribute to this discourse by examining the role of firm resources and dynamic capabilities, respectively, in sustaining competitive advantage, suggesting that environmental sustainability can be a strategic resource or capability in rapidly changing technological environments. Fornell & Larcker [103] and Podsakoff et al. [104] provide methodological insights, the former cautioning against the pitfalls of common statistical tests in structural equation modeling, and the latter discussing the influence of method biases in behavioral research, indirectly underscoring the complexity of measuring and interpreting the impacts of green strategies on firm performance. Porter & Van der Linde [19] introduces a paradigm shift, arguing that environmental regulation, contrary to being a hindrance, can spur innovation and enhance competitiveness. Berrone et al. [105] and Russo & Fotus [106] both highlight the positive linkage between environmental performance and economic performance, with the former emphasizing the role of regulatory and normative pressures in fostering environmental innovation, particularly in firms with significant pollution relative to their peers.

4.3. Bibliographic coupling network analysis

Diverging from co-citation analysis, bibliographic coupling employs a prospective viewpoint, concentrating on emerging trends and research areas within the literature, selected by authors with similar bibliographies. In this method, documents are interconnected through their mutual citations. Notably, bibliographic coupling's focus lies not on the cited papers themselves, but on the nascent sub-fields within the broader scholarly discourse. This investigation utilizes a bibliographic analysis of 922 documents that are referenced by the green technologies in companies' strategies publications included in this sample, facilitating the identification of salient publications and the assembly of articles into distinguished clusters. Considering the extensive array of documents associated with the field under study, criteria were established to enhance network interpretability and highlight key publications, thus stipulating a minimum of 30 citations per paper. This approach yielded 224 applicable publications. Like the methodology employed in co-citation analysis, a threshold of 30 citations represents an optimal equilibrium between information reduction due to an excessively high cut-off and a steep decline in the modularity index for a cut-off of <30. Following further refinements, i.e. excluding the documents that did not show any connections within the network, the final sample consisted of 198 papers. Table 4 delineates the documents within each cluster, alongside their coupling association strength, labels, and descriptive factors such as cluster size and average publication year. The bibliographic network provided by VOSviewer exhibits a density of 0.1, which denotes a lower-than-moderate degree of interconnection within the network [59] whereas the modularity index of the 11 clusters that the bibliometric software identified is 0.42, indicating relatively considerable interlinkages among all the documents included in the analysis [76]. Out of the ten clusters that emerged from VosViewer, however, two will not be considered in the following discussion due to their relative significance within the sample, being both of them composed of <10 papers each, which appeared to be poorly related to a first abstract screening. Eventually, one last cluster, composed of 2 papers only, rather than being excluded, was merged with another one having the same focus (cluster 5). The 7 remained clusters are arranged in a time-sequential manner, dictated by the average publication year of the documents contained within each cluster. The reference to individual cluster members can be found in Table 5. For length restrictions, only the first author will be reported.

4.3.1. Bibliographic coupling cluster 1: China's leading role

A common theme across these studies is exploring how green technology innovation, environmental regulation, and the role of cultural and societal factors can help drive economic growth while mitigating environmental impact. Xie & Teo [108] addresses the role of green technology innovation in facilitating cleaner industrial upgrading within China, highlighting the complex effects of environmental regulation on such processes. Similarly, Yang et al. [109] and Li et al. [110] study the dynamics of green innovation ecosystems and the positive effects of new media and environmental regulations on corporate green technology innovation. Costantini et al. [111] and Fernandes et al. [112] broaden the scope by examining the diffusion pathways of green technologies and their impacts on sectoral environmental performance and green growth's contribution to economic growth, respectively. These studies underscore the interconnectedness of eco-innovations along the supply value chain and the central role of sustainable technology transfer in promoting economic sustainability. Orlando et al. [113] and Lian et al. [114] offer insights into the cultural and policy dimensions influencing green technology management and innovation, with the former highlighting the significance of societal culture and government investments in eco-innovation, and the latter examining the nuanced effects of environmental regulation on substantive versus symbolic green innovation. Tang et al. [115], Zhou & Wang [116], and Zhou & Du [117] present analyses of the infrastructure and policy mechanisms that foster green technology innovation, including telecommunications infrastructure, carbon emissions trading schemes, and the interplay between financial development and environmental regulations. These studies collectively suggest that strategic investments in green technology and supportive policy frameworks are essential for enhancing environmental and economic outcomes. Xu et al. [118] and Ikram et al. [119] focus on the role of green finance policies and strategic planning in advancing green technology innovation, with Xu evaluating the action points of China's Green Finance Pilot Policy. Lastly, Yang et al.

Table 4
Overview of bibliographic coupling clusters.

Documents in cluster and association strength (in parentheses)	Label	Description	Cluster number	Size	Year (avg.)
Xie (2022), (148); Yang (2021), (103); Costantini (2017), (89); Fernandes (2021), (86); Li (2023), (76); Orlando (2022), (75); Lian (2022), (73); Tang (2021), (71); Zhou (2022), (71); Zhou (2021), (69); Xu (2023), (66); Ikram (2021), (63); Hottenrott (2016), (61); Zeng (2022), (61); Liu (2021), (61); Zhang (2022A), (58); Wang (2021B), (54); Shahzad (2022), (54); Yang (2022), (53); Guo (2020), (43); Sun (2020), (43); Kivimaa (2006), (41); Deng (2019), (40); Chien (2022), (34); Feng (2021), (31); Zhu (2021), (29); Zhang (2022B), (29); Li (2021), (29); Du (2022), (29); Zeng (2021), (25); Li (2022), (23); Wang (2022A), (23); Peng (2020A), (17); Luo (2019), (17); Gao (2021), (16); Aldieri (2019), (12); Zhang (2020), (11); Huang (2023), (10); Li (2019), (9); Ali (2021), (8); Shen (2020), (6); Jin (2018), (4); Yu (2020), (4)	China's Leading Role	Cluster 1 investigates the impact of green technology and environmental policies on sustainable economic growth, with a focus on China's industrial upgrading.	1	43	2021
Luo (2016), (68); Mishra (2020), (54); Chen (2017), (50); Mishra (2021A), (49); Mashud (2021A), (41); Mashud (2021B), (39); Ma (2021B), (34); Lu (2020), (32); Yang (2020), (31); Wang (2020), (29); Dou (2021), (27); Zhang (2021B), (26); Taleizadeh (2021), (25); Nielsen (2019), (25); Hussain (2020), (24); Chemama (2019), (22); Ding (2018), (21); Yu (2021), (18); Alizamir (2016), (16); Bhardwaj (2016), (16); Niu (2019), (15); Chalmardi (2019), (11); Puller (2006), (9); Li (2020), (8); Gong (2013), (6); Usmani (2021), (2); Fadda (2022), (1)	Reducing CO2 Emissions	Cluster 2 studies strategies for reducing carbon emissions through green technology investments and policy-driven corporate cooperation.	2	27	2019
Abbas (2019), (62); Wang (2022B), (51); Sahoo (2022), (41); Abbas (2022), (35); Sang (2015), (33); Mohiuddin (2018), (30); Zhang (2018), (17); Bilal (2022), (16); Yang (2016), (15); Shobande (2022), (9); Bibri (2020), (9); Batool (2019), (8); Zhang (2015), (6); Jim (2013), (2); Zhang (2011), (1)	Green Knowledge Management	Cluster 3 emphasizes the critical role of GKM in enhancing green innovation and achieving sustainability goals.	3	15	2018

(continued on next page)

Table 4 (*continued*)

Documents in cluster and association strength (in parentheses)	Label	Description	Cluster number	Size	Year (avg.)
Bhupendra (2016), (177); Bhupendra (2015), (168); Khan (2021), (141); Cristina De Stefano (2016), (121); Fernando (2019), (111); Yacob (2019), (100); Qi (2020), (99); Weigelt (2015), (88); Dangelico (2013), (87); Kim (2013), (81); Aragon-Correa (2016), (74); Meyskens (2013), (70); Rauer (2015), (63); Mrkajic (2019), (55); Ma (2021A), (49); Wu (2021), (48); Xia (2015), (39); Mcknight (2018), (38); Yin (2018), (38); Sadovnikova (2017), (32); Kishna (2017), (26); Niesten (2017), (21); Cohen (2014), (20); Mishra (2021B), (20); Malek (2014), (18); Islam (2018), (16); Hargadon (2012), (14)	Green Capabilities	Cluster 4 examines how firms adopt cleaner technologies and green innovations for sustainability and competitive advantage.	4	28	2016
Xia (2019), (47); Bhandari (2019), (36); Xia (2017), (29); Tseng (2013), (11); Ren (2017), (11); Hrovatin (2016), (10); Sun (2017), (9); Cruz (2016), (8); Belhadi (2020), (8); Tarei (2021), (8); An (2017), (6); Vanapalli (2021), (3); Fiorentino (2017), (2); Nissim (2018), (2); Maxim (2014), (2); Juwarkar (2009), (1); Sangle (2011), (10); Montalvo (2007), (10)	Green Tech Adoption	Cluster 5 highlights the adoption, challenges, and sustainability assessment of green technologies across multiple sectors.	5	18	2016
Orsatti (2020), (131); Coenen (2010), (114); Browne (2012), (80); Musiolik (2012), (80); Hall (2018), (71); Soderholm (2018), (70); Foxon (2008), (65); Wadin (2017), (63); Hillman (2011), (62); Mignon (2016), (57); Bohnsack (2014), (56); Lubik (2016), (56); Wicki (2019), (54); Bolton (2016), (51); Sushandoyo (2014), (48); Heiskanen (2015B), (44); Caniels (2008B), (38); Schmidt (2016), (32); Kemp (1998), (31); Huenteler (2016), (21)	Systemic Innovation	Cluster 6 focuses on the systemic interplay between innovation, policy frameworks, and strategic management in fostering the development and diffusion of sustainable technologies.	6	30	2014
Desing (2020), (33); Partidario (2002), (21); Lam (2009), (18); Tan (2010), (12); Moors (2005), (11); Robèrt (2002), (9); Wang (2021C), (9); Phdungsilp (2011), (8); Green (2002), (8); Almeida (2015), (8); Nwankwegu (2022), (7); Pitt (2011), (7); Lee (2018), (7); David (2022), (6); Oyetibo (2017), (5); Jansen (2003), (5);	Urban Sustainability	Cluster 7 centers on sustainable urban development through clean technologies, innovative planning, and systemic change.	7	22	2013

(*continued on next page*)

Table 4 (*continued*)

Documents in cluster and association strength (in parentheses)	Label	Description	Cluster number	Size	Year (avg.)
Pandey (2021), (5); Maes (2017), (3); Fernandez (2018), (2); Mcgee (2009), (2)					

Notes: The table reported only the first author's name, the year of documents and the number for citations due to spatial constraints. For the same reasons these authors have been not included in the references.

Table 5
Co-cited reference cross-checking coupling cluster.

	CC Cluster 1	CC Cluster 2	CC Cluster 3	CC Cluster 4
BC Cluster 1	0	0	6 (0.7 %)	0
BC Cluster 2	54 (4.2 %)	2 (0.1 %)	0	4 (0.3 %)
BC Cluster 3	0	10 (1 %)	2 (0.2 %)	11 (1.1 %)
BC Cluster 4	0	21 (1.3 %)	17 (1 %)	82 (5 %)
BC Cluster 5	0	1 (0.1 %)	2 (0.3 %)	2 (0.3 %)
BC Cluster 6	0	14 (1 %)	80 (6.1 %)	9 (0.7 %)
BC Cluster 7	0	0	6 (0.7 %)	0

[109] explores the impact of manufacturing intelligence on green innovation performance, indicating the potential of digital transformation to bolster environmental sustainability efforts.

4.3.2. Bibliographic coupling cluster 2: reducing CO2 emission

This second cluster revolves around the exploration of strategies for reducing carbon emissions through the adoption of green technologies and the implementation of carbon tax, cap-and-trade policies, and other regulatory mechanisms. Notably, the research emphasizes the significance of co-opetition [120], sustainable economic production models [68,121], and strategic investments in green technologies [122–125] as essential elements in enhancing both environmental sustainability and economic profitability. The papers highlight the importance of integrating emission-sensitive demand considerations into the operational and strategic decision-making processes of firms [126]. This integration is showcased as a critical factor in achieving low-carbon manufacturing and sustainable supply chain management. Moreover, the studies highlight the role of governmental policies in influencing corporate behaviors towards more environmentally friendly practices [127–130]. The research underlines that while investments in green technologies can lead to improved environmental and economic outcomes, the specific impacts depend on various factors including market structure, competition, and the design of regulatory frameworks. Through game theory analysis, mathematical modeling, and system dynamics, these papers offer insights into how different market power structures and policy interventions can influence the optimal pricing, technology investment, and cooperative strategies among firms, leading to varied implications for carbon emissions reduction and profitability [122,123,126,129]. Additionally, the significance of supply chain collaboration and the strategic role of inventory management in green supply chains are explored [121,125], revealing that the adoption of green technologies not only enhances firms' environmental performance but also their economic viability.

4.3.3. Bibliographic coupling cluster 3: green knowledge management

Within the publications of this cluster, significant emphasis is placed on Green Knowledge Management (GKM) as a critical factor in advancing sustainable development and environmental innovation. This focus is particularly evident in the works of Abbas & Sağsan [131], Wang et al. [31], and Sahoo et al. [132], which collectively underscore the role of GKM in fostering green innovation and contributing to Corporate Sustainable Development (CSD) activities. The former lays the groundwork by examining how knowledge management processes, specifically knowledge creation, acquisition, sharing, and application, significantly impact green technology and management innovation. This study provides a comprehensive view of the instrumental role of KM in enhancing the environmental, social, and economic facets of sustainability, highlighting the crucial dynamic between KM processes and green innovation outcomes. Building on this, Wang and coauthors introduce the concept of Green Knowledge Management (GKM) and investigate its influence on organizational capabilities to achieve Sustainable Development Goals (SDGs). This study further explores how an organizational green culture (OGC) can amplify the effectiveness of GKM in promoting green innovation. Wang's findings reveal that GKM not only strengthens an organization's ability to innovate sustainably but also asserts that a supportive green culture enhances this relationship, thereby facilitating the achievement of SDGs. Sahoo and coauthors, eventually, extend the discourse by focusing on green knowledge acquisition's role within the framework of GKM. This research elucidates how green knowledge acquisition is instrumental in improving GKM and green technology innovation, ultimately leading to better corporate environmental performance. The study introduces the concept of resource commitment as a moderating factor, suggesting that the allocation and budgeting of resources towards green practices are critical for leveraging the benefits of GKM.

4.3.4. Bibliographic coupling cluster 4: green capabilities

Recent literature underscores the importance of integrating cleaner technology strategies and green process innovations within firm operations to enhance competitive positioning and respond to increasing environmental concerns [133–135]. These studies highlight the necessity for firms to adopt proactive environmental strategies, focusing on innovative capabilities, top management's risk-taking abilities, and the adaptation to regulatory uncertainties [134,136]. Furthermore, the role of green technology in facilitating eco-innovation and its impact on business sustainability, mediated by service innovation capability, is increasingly recognized as a significant driver for long-term competitive advantage [70]. Yacob et al. [137] and Qi et al. [138] explore the adoption of green initiatives and green innovation, respectively, within the manufacturing sector, emphasizing the mediating effects of managerial intention towards green and the moderating effects of green technology adoption on environmental sustainability. Wu et al. [139] adds to this discussion by analyzing compliance strategies in family businesses, showing a blend of substantial environmental improvements and impression management tactics influenced by public pressure and business-government relationships, highlighting the complexity of strategic environmental responses in varying organizational contexts. These contributions suggest that a firm's strategic response to environmental challenges is not only a function of internal capabilities but is also influenced by external pressures from regulators, competitors, and other stakeholders [140–142]. Moreover, the intersection of patented environmental innovations with non-environmental innovations, as discussed by Aragon-Correa & Leyva-de la Hiz [143], and the exploration of partnership diversity in green-technology ventures [144], provide insights into how firms can leverage external collaborations and technological innovations to achieve environmental sustainability goals.

4.3.5. Bibliographic coupling cluster 5: green tech adoption

Common themes in this fifth cluster include the identification and overcoming of barriers to technology adoption, the importance of sustainability assessments, and the development of frameworks for decision-making in the context of green technologies and cleaner production methods. Xia et al. [145], Bhandari et al. [146], and Xia et al. [147] discuss the challenges and frameworks for green technology

adoption, emphasizing the importance of overcoming operational, psychological, and financial barriers through comprehensive methodologies like FAHP and AHP. These studies underscore the critical role of aligning technological solutions with organizational competencies and sustainability goals. Ren et al. [148], Hrovatin et al. [149], and An et al. [150] explore the assessment of sustainable technologies in wastewater treatment, energy efficiency, and groundwater remediation, respectively, highlighting the use of multi-criteria decision-making (MCDM) methods to evaluate alternatives based on economic, environmental, social, and technological criteria. Tseng et al. [151] and Vanapalli et al. [152] address broader sustainability issues within supply chains and waste management during the COVID-19 pandemic, focusing on green supply chain management, circular economy principles, and the need for sustainable consumption and production patterns. Sun et al. [72] and Belhadi et al. [153] explore the impact of green technology innovation on industry efficiency and waste management strategies, presenting models to evaluate technological solutions' ecological and economic benefits. Cruz & Katz-Gerro [154] and Tarei et al. [155] discuss the behavioral and policy aspects of adopting green technologies, emphasizing the gap between values and practices and the interdependencies among barriers to technology adoption, such as infrastructure and consumer awareness.

4.3.6. Bibliographic coupling cluster 6: systemic innovation

The matter of contention across these papers is the investigation of the dynamics between innovation systems, policy frameworks, and the strategic management of knowledge and resources to foster the development and diffusion of sustainable technologies. Orsatti et al. [156] highlight the significance of inventor teams' capacity to creatively recombine knowledge in the context of green technology innovation, underscoring the role of experience and policy environments in enhancing innovation outcomes. This notion is echoed in Coenen & Diaz Lopez [157], which digs into theoretical frameworks like sectoral systems of innovation (SSI), technological innovation systems (TIS), and socio-technical systems (ST-Systems), suggesting a systems approach to understanding innovation and its policy implications. Further, the papers collectively emphasize the importance of governance, policy, and institutional frameworks in facilitating or hindering the adoption of sustainable technologies. For instance, Browne et al. [158] and Mignon & Bergek [159] discuss the barriers to market penetration and diffusion of alternative fuels and renewable energy technologies, respectively, pointing to the need for frameworks that can address these barriers. This is complemented by the work of Musiolik et al. [160] and Soderholm et al. [161], who examine the role of formal networks and policies in supporting technological innovation systems and sustainable transitions. Moreover, several studies focus on the commercialization challenges and business model innovations necessary for the widespread adoption of sustainable technologies. Hall et al. [162] discuss the downstream commercialization challenges, including regulatory hurdles, while Wadin et al. [163] and Bohnsack et al. [66] explore the dynamics of business model innovation in the context of sustainability, highlighting the differing approaches of incumbent and entrepreneurial firms. Lubik & Garnsey [164] further examine the unique challenges faced by university spin-outs in commercializing advanced material technologies, emphasizing the trial-and-error nature of business model development.

4.3.7. Bibliographic coupling cluster 7: urban sustainability

Central to this final cluster is instead the recognition of urban areas as critical arenas for implementing circular economy (CE) principles and sustainability innovations. Desing et al. [165] introduce a resource-based approach to CE that is pertinent to urban contexts, emphasizing the need for a paradigm shift in environmental management that aligns with sustainable urban development. This notion is echoed by Lam et al. [166], who identify key factors for the successful specification of green construction, an essential component of sustainable urban development. These factors include stakeholder involvement and the integration of green technology, highlighting the collective effort required for urban sustainability. The work of Phdungsilp [107] on the Göteborg 2050 project exemplifies the effective use of backcasting methodologies in urban planning to envision and actualize a sustainable city. This approach fosters a long-term perspective that is crucial for addressing the multifaceted challenges of urban sustainability, suggesting that visionary planning can significantly accelerate the transition towards sustainable urban environments. Similarly, Green & Vergragt [167] address the necessity of combining technological and social innovations within urban settings to achieve a high factor of environmental efficiency, pointing to the indispensable role of cultural and lifestyle shifts alongside urban technological transformations. Moreover, Almeida et al. [168] highlight the urgent need for sustainable urban patterns, pointing out the role of improved corporate management and policy integration in promoting cleaner technologies within urban areas.

4.4. The author's keyword co-occurrence analysis

Bibliometric analysis is a valuable tool for understanding the structure and dynamics of scientific research within a field by examining the co-occurrence of keywords in literature. This analysis involves mapping out relationships between different concepts, often represented as nodes in a network where connections indicate co-occurrences. Through this approach, clusters of closely associated nodes emerge, reflecting coherent sub-themes or topics within the field [39]. Centrality measures like betweenness and closeness are commonly used in bibliometrics to assess the significance of keywords in the network. Betweenness centrality highlights a keyword's potential to bridge different research areas, while closeness centrality indicates the accessibility and relevance of a keyword within the network [169]. Researchers can utilize tools like Bibliometrix to conduct comprehensive science mapping analyses focusing on the author's keywords to uncover the research landscape's structure. This method can reveal interconnected themes represented by clusters based on keyword co-occurrence, providing insights into the main topics under investigation and their interconnections. Such analyses are crucial for tracking research trends, understanding the evolution of fields, and identifying opportunities for interdisciplinary collaboration [39]. This approach not only sheds light on the main topics but also reveals how these topics are related, offering valuable insights into research trends and potential interdisciplinary collaboration opportunities [39]. In this case, our study, filtering for the author's keywords with a minimum number of edges equal to 2, identified 40 keywords, divided into 8 unique clusters in a network, each representing interconnected themes based on keyword co-occurrence, as represented in Fig. 5.

Cluster 1 (blue) is dominated by "green technology" with a betweenness centrality of 221.21, signaling its central role in connecting different concepts, as well as suggesting a strong focus on technology-specific discussions. "Supply chain" has a betweenness of 36.00, and "innovation" follows with 10.48, indicating their importance but more niche focus compared to "green technology". The inclusion of "covid-19″ may suggest a recent focus on the pandemic's impact on green technology adoption. Cluster 2 (red) is instead led by "green technology innovation" with a betweenness of 214.70, highlighting its significance in bridging various themes. "China" shows a betweenness of 14.16, indicating a significant amount of research focused on Chinese practices or policies related to green technology, while "environmental performance" has a notable value of 36.60, and "eco-innovation" follows with 22.89, pointing to a focus on practical outcomes and new environmental initiatives. Cluster 3 (green) centers around "sustainability" with the highest betweenness of 263.62, underscoring its critical importance. "Sustainable development" has a betweenness of 195.29, with "green innovation" at 77.30, showing a strong engagement with the development and implementation of sustainable technologies. Cluster 4 (purple)

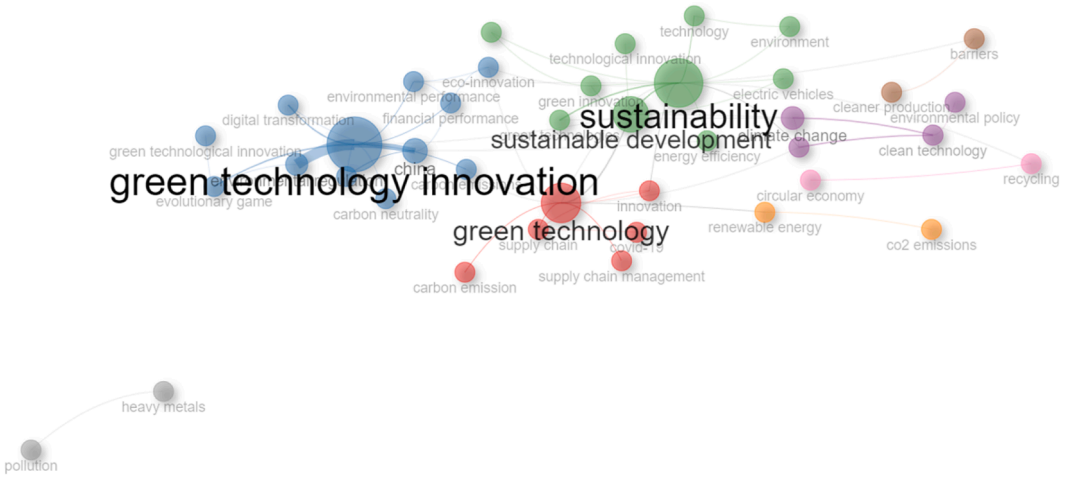


Fig. 5. Author's Keywords Co-Occurrence Network.

features "game theory" with a betweenness of 47.77, suggesting a strategic approach within this cluster. "Clean technology" has a betweenness of 36.00 and "climate change" comes in with 27.91, pointing to a focus on analytical and policy-driven research. Cluster 5 (orange) is built around "renewable energy" with a betweenness of 36.00, highlighting the focus on energy sources as a significant aspect of green technology integration. Cluster 6 (brown) discusses "barriers" with a betweenness centrality of 36.00, which may reflect on the obstacles encountered in transitioning to greener production methods, while cluster 7 (pink) includes "recycling" with a betweenness centrality of 36.00, indicating its role in the discussion about waste management and resource use within the circular economy. Eventually, cluster 8 (grey) consists of two author's keywords, "heavy metals" and "pollution", that, uniquely, show a closeness centrality of 1.0000, although their betweenness is 0.00, suggesting they are highly specific topics that are directly connected to all other terms within their cluster.

Additionally, through Bibliometrix, a thematic evolution map was developed, as displayed in Fig. 6, to grasp the dynamics of keywords over time. In delineating temporal segments within the presented analysis, deliberate choices were made to align with the availability of data to render a factual representation of the evolutionary scholarly discourse. The initial span, 1992–2008, was selected to embody the array of papers that surfaced in the co-citation analysis, while also reflecting the average publication years of the most significant works considered. The ensuing segment, 2009–2018, adheres to a similar logic, yet pivots on bibliographic coupling methodology, mapping the intellectual structure of the field through interconnected publications. The final slice, 2019–2023, was determined to capture current trends, considering the latest socio-economic and health-related vicissitudes that have indubitably influenced academic focus and discourse. In the context of our paper focusing on the integration of green technologies within business strategies, these time frames serve to illustrate shifts in focus on various facets of sustainability and green innovation:

- 1992–2008: During this era, there appears to have been an initial drive toward the comprehension and incorporation of cleaner and more sustainable practices within businesses, signaled by the emphasis on broad concepts such as "environmental management", "cleaner production", "clean technology", "environmental policy", "sustainability", and "innovation".
- 2009–2018: This period witnesses the ascent of terms like "pollution", "environmental regulation", "eco-innovation", "sustainable development", "heavy metals", "alliances" and "green technologies". This suggests an evolution toward more precise environmental regulation and an understanding of eco-sustainability within innovation, as well as the initiation of strategic collaborations or alliances.
- 2019–2023: The recent years have shown a robust interest in "sustainability", "green technology innovation", "phytoremediation", "technological innovation", and "environmental sustainability". This denotes a significant push toward innovation and the application of green technologies in corporate strategies, with terms like

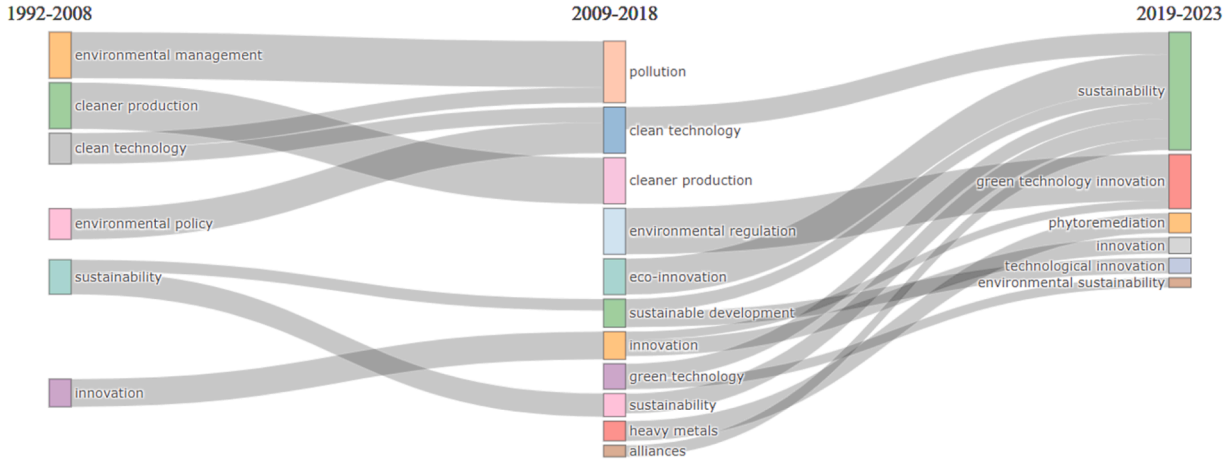


Fig. 6. Thematic Evolution of Author's Keywords.

"phytoremediation" gaining prominence, possibly reflecting a growing interest in more advanced and specific environmental sustainability solutions.

5. Discussion

What emerged from the results of our study is an intriguing evolution of research focus and methodology within the field of green technologies and sustainable business strategies. This shift not only reflects the changing priorities and advancements in the field but also suggests a progression from foundational theoretical frameworks to more applied, innovative, and interdisciplinary approaches.

At first, the co-citation analysis primarily highlighted seminal works and foundational theories that have shaped the understanding of sustainability within business practices. These clusters tend to emphasize established concepts such as sustainable supply chains, Porter's Hypothesis, holistic sustainability, and strategic green integration, reflecting a focus on the underpinning theories and methodologies that guide sustainable business research. The bibliographic coupling clusters, on the other hand, demonstrate a shift towards applied innovations, policy analysis, and the exploration of green technology's role within specific contexts, such as China's leadership in green technology innovation and strategies for CO2 emission reduction. The role of China as a prominent player in these clusters, underscored by the descriptive analysis, reflects not just a geographic focus but also the impact of national policies and global agreements on research orientations. China's aggressive push towards green technologies, influenced by its commitments under the Paris Agreement and its own national development goals, exemplifies how geopolitical and economic ambitions drive the focus of current research. This is further illustrated by the international collaborations and the regional approach to sustainability, indicating a shift towards more localized and policy-driven research within the bibliographic coupling clusters. This suggests a move from theoretical exploration to practical application and the testing of concepts in real-world scenarios.

Such ongoing transformation, moreover, indicates a growing emphasis on geographical specificity and policy impacts. While foundational research provides a broad theoretical base, applied research seen in the coupling clusters often focuses on specific national or regional contexts, highlighting the importance of local policies, economic conditions, and cultural factors in shaping sustainable business practices. The progression reflects an increasingly interdisciplinary and cross-sectoral approach to research. Early co-citation clusters may have focused more on business and environmental science perspectives. Still, bibliographic coupling clusters reveal a broader integration of disciplines, including technology innovation, public health, and even media studies, showcasing the multifaceted nature of sustainability challenges and solutions. The bibliographic coupling analysis also shows a dynamic response to global challenges, such as the COVID-19 pandemic, which may not be as prominent in the co-citation analysis. This suggests that recent research is rapidly evolving to address immediate global challenges, integrating sustainability with resilience and adaptation strategies.

The descriptive analysis highlighted a significant uptick in publications related to green and sustainable technologies, particularly from 2015 onwards, which aligns with the global ratification of the Sustainable Development Goals and the Paris Agreement. This growing scholarly attention suggests a broader academic and practical interest in translating foundational sustainability concepts into actionable business strategies. The surge in publications post-2018, especially, reflects an intensified focus on innovative solutions and interdisciplinary approaches to sustainability, corroborating the shift observed from co-citation to bibliographic coupling clusters. Citation patterns from the descriptive analysis revealed the significant influence of certain key works, as emerged from the co-occurrence analysis, that bridge theoretical frameworks and practical applications, aligning with the shift from co-citation to bibliographic coupling clusters. Papers that focus on strategic niche management, the impact of policy and governance on green technology adoption, and the role of innovation in enhancing sustainability underscore the evolving research agenda. The prominence of works that not only conceptualize but also empirically examine the integration of green technologies into business models confirms a maturation of the field towards actionable insights and strategies.

5.1. Implications for scholars

The diversity of journals identified in the descriptive analysis, ranging from technical and applied sciences to environmental and ecological research, and business and environmental strategies, supports the observed transition to a more interdisciplinary and applied research focus. This diverse publishing landscape highlights the multifaceted nature of sustainability challenges and the necessity of cross-sectoral knowledge to address them. Nevertheless, the relatively sparse representation of business-focused journals in the green technology domain suggests a nascent, yet potentially explosive, domain ripe for scholarly exploration. This gives scholars a dual opportunity: to pioneer in a relatively untapped space and bridge the evident gap where newer publications seem disjointed from their predecessors.

As both the co-citation analysis and the bibliographic coupling were completed, providing a backward and forward perspective on the field of the integration of green, clean, and sustainable technologies within businesses' strategies respectively, it was interesting to look for possible linkages between the two of them. Therefore, as in Anwar [170], the next step was to further analyze which co-citation clusters were cited by the coupling clusters to recognize the theoretical roots of each bibliographic coupling cluster. The results, reported in Table 5, nevertheless, were not particularly enlightening. It emerged that, out of the four co-citation clusters, the publications from cluster 3 "Strategic Green Integration" were the relatively most cited by the majority of the papers from the bibliographic coupling clusters, particularly from cluster 6 "Systemic Innovation". Clusters 2 "Porter's Hypothesis" and 4 "Holistic Sustainability" of the co-citation analysis follow with even more modest figures, except for the link between the latter and the fourth bibliographic cluster "Green Capabilities". Lastly, for what concerns the first co-citation cluster, "Sustainable Supply Chains", the only connection that was found out is with the publications pertaining to the second bibliographic cluster "Reducing CO2 Emissions", although again not very significative. Overall, the resulting percentages score relatively low figures across the board: this suggests that, given the ongoing evolution of scientific and academic contributions in this field, there is currently no well-established foundation. Instead, technological advancements predominantly shape the trajectory, underscoring their significant role in driving progress. These disconnects hint at an evolving academic landscape. Scholars are presented with both a challenge and an opportunity here, i.e. to weave these disparate threads into a cohesive tapestry of understanding. Furthermore, the potential for interdisciplinary collaboration could not be overemphasized. By melding insights from technology, environment, and business domains, scholars can spearhead a holistic and enriched academic discourse.

5.2. Implications for managers

The observed shift in the research landscape towards the practical application of green technologies and sustainable business strategies underscores several critical areas for managerial action and strategic consideration in today's rapidly evolving business environment. Firstly, the prominence of China in leading green technology innovation suggests an emerging paradigm where managers, particularly those in multinational corporations or businesses looking to expand, should consider engaging more deeply with Chinese markets, partners, and innovation ecosystems. China's aggressive advancement in green technologies, backed by supportive government policies, offers a fertile

ground for collaborative projects, joint ventures, or for sourcing cutting-edge sustainable technologies. Managers should stay updated on the developments in this space, seeking opportunities to integrate such innovations into their business models to drive sustainability and competitive advantage. Given the emphasis on geographical specificity and policy orientation, managers should consider localized strategies that align with regional environmental policies, market conditions, and consumer preferences. Simultaneously, fostering international collaborations can provide access to a wider pool of knowledge, technologies, and best practices in sustainability, enhancing the firm's ability to navigate the complexities of global markets while advancing its sustainability agenda. Moreover, the focus on reducing CO2 emissions and leveraging green knowledge management within bibliographic coupling clusters highlights the importance of integrating sustainability deeply within business strategies. Managers are advised to move beyond viewing sustainability as a compliance requirement or a CSR initiative, treating it as a core strategic pillar. This involves embedding sustainability into the product lifecycle, from design through to production and end-of-life, to drive not only environmental benefits but also operational efficiencies and potential cost savings. Strategic investments in R&D for green technologies and fostering a culture of sustainability within the organization can enhance brand reputation, customer loyalty, and open new market opportunities. Acknowledging the dynamic response to global challenges, such as the COVID-19 pandemic, managers must cultivate organizational agility to adapt to sudden market changes and global disruptions. This involves not only investing in resilient supply chains and flexible business operations but also in the capability to pivot quickly towards new business opportunities that such disruptions may present, particularly in the domain of sustainable practices and green technologies. Eventually, the interdisciplinary nature of current research on green technologies and sustainable practices highlights the value of cross-disciplinary innovation within organizations. Managers should foster collaborative environments where insights from diverse fields—engineering, environmental science, business strategy, and even public health—can intersect to spur innovation. This approach can lead to the development of novel solutions that address sustainability challenges in holistic and effective ways, potentially unlocking new business models or market niches.

Therefore, the insights derived from our analysis point towards a strategic imperative for managers to actively engage with the latest developments in green technology and sustainability research. By embracing innovation, fostering interdisciplinary collaboration, aligning with global trends, and leveraging strategic partnerships, businesses can navigate the uncertainties of the modern business landscape while contributing positively to environmental sustainability.

6. Conclusions

Our study highlights a significant shift in green technologies and sustainable business strategies, moving from theoretical foundations to practical, interdisciplinary approaches. Initially focused on seminal works on sustainable supply chains and the Porter's Hypothesis, recent research pivots toward innovative applications, with a notable emphasis on China's green technology advancements and CO2 reduction strategies. This reflects a broader trend toward applied research influenced by geographical, policy, and economic considerations. The transition signifies a move from theoretical models to real-world applications, integrating diverse disciplines such as technology innovation and public health. This is echoed in the increase of publications post-2015, aligning with global sustainability efforts. Despite a varied journal landscape, the scarcity of business-focused publications suggests an emerging field ripe for exploration. The analysis reveals both challenges and opportunities for scholars and practitioners to bridge gaps in current research, emphasizing technological advancements and the need for interdisciplinary collaboration. For managers, this evolution underscores the strategic importance of aligning with sustainability trends, engaging in international partnerships, and adopting localized, innovative strategies to navigate the complexities of sustainability and green technology in a global business environment.

Nevertheless, this study, while contributing to new insights, possesses indeed some limitations. Methodologically, the reliance on the Web of Science Core Collection as the exclusive source for our database may have induced biases. Scope and delimitation were also constrained by considering only English-written academic works, and the simultaneous specificity and generality of certain keywords might have excluded pertinent publications. While these issues are intrinsic to bibliometric analysis, decisions were made with caution to ensure the academic pertinence of this work. Additionally, interpretational constraints should be acknowledged. Reading, understanding, and interpreting the clusters derived from the bibliographic coupling, co-citation analysis, and co-occurrence analysis were conducted solely by the research team. Even though discussions were intensive, the broad themes may create room for misinterpretation.

The analysis so far suggests several key areas for future research: firstly, there is a burgeoning need to study deeper into how government policies, innovation ecosystems, and corporate strategies can be synergistically aligned to foster sustainable development. This requires a granular investigation into the mechanisms through which policy can catalyze innovation and how businesses can adaptively align their strategies to these frameworks.

Moreover, the aftermath of global disruptions such as the COVID-19 pandemic has underscored the necessity for resilience and adaptability in business strategies aimed at sustainability. Future research should aim to develop models that can anticipate and mitigate the impacts of such global challenges, ensuring businesses not only survive but thrive by turning adversities into opportunities for sustainable innovation. The emphasis on geographic specificity in our findings suggests a rich field of study in understanding how local contexts — cultural, economic, and environmental — influence the effectiveness of sustainability strategies. Tailored research that considers these local nuances can offer invaluable insights into crafting more effective, localized sustainability interventions. Additionally, the diversity observed in the range of topics and journals highlights the critical importance of interdisciplinary collaboration. Future studies should seek to bridge gaps between fields, as in our intentions with this work, fostering a holistic understanding of sustainability that can lead to more innovative and comprehensive solutions. Lastly, our research points towards the necessity of continuous innovation and strategic adaptation in the face of a rapidly changing global landscape. Future academic fellows should focus on how businesses can proactively engage with green technologies, integrating sustainability into the core of their operations to navigate the challenges and seize the opportunities presented by the green transition. This not only ensures their long-term viability but also contributes to the broader goal of sustainable development, setting a course towards a more resilient and environmentally conscious global economy.

CRediT authorship contribution statement

Rocco Pavesi: Data curation, Writing – original draft, Formal analysis, Software, Writing – review & editing. **Luigi Orsi:** Conceptualization, Writing – original draft, Methodology, Supervision, Writing – review & editing. **Luca Zanderighi:** Supervision, Validation, Writing – original draft.

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.

Acknowledgement

This study was carried out within the Agritech National Research Center and received funding from the European Union Next-GenerationEU (PIANO NAZIONALE DI RIPRESA E RESILIENZA (PNRR) – MISSIONE 4 COMPONENTE 2, INVESTIMENTO 1.4 – D.D. 1032 17/06/2022, CN00000022). This manuscript reflects only the authors' views and opinions, neither the European Union nor the European Commission can be considered responsible for them.

Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.sftr.2025.100922.

Data availability

Data will be made available on request.

References

[1] Y. Zhu, H. Zhang, A.B. Siddik, Y. Zheng, F.A. Sobhani, Understanding corporate green competitive advantage through green technology adoption and green dynamic capabilities: does green product innovation matter? Systems. (Basel) 11 (9) (2023) 461, https://doi.org/10.3390/systems11090461.
[2] Y. Chen, S. Jin, Corporate Social responsibility and green technology innovation: the moderating role of stakeholders, Sustainability. 15 (10) (2023) 8164, https://doi.org/10.3390/su15108164.
[3] M.T. Islam, Newly developed green technology innovations in business: paving the way toward sustainability, Technol. Sustain. 2 (3) (2023) 295–319, https://doi.org/10.1108/TECHS-02-2023-0008.
[4] R. Qiu, S. Hou, X. Chen, Z. Meng, Green aviation industry sustainable development towards an integrated support system, Bus. Strategy. Environ. 30 (5) (2021) 2441–2452, https://doi.org/10.1002/bse.2756.
[5] X. Zhao, W. Pan, The characteristics and evolution of business model for green buildings: a bibliometric approach, Eng. Constr. Architect. Manage. 29 (10) (2021) 4241–4266, https://doi.org/10.1108/ecam-08-2020-0657.
[6] P. Lindgren, N. Knoth, S. Sureshkumar, M. Friedrich, R. Adomaityte, green multi business models" how to measure green business models and green business model innovation? Wirel. Pers. Commun. 121 (2) (2021) 1303–1323, https://doi.org/10.1007/s11277-021-09189-2.
[7] N. Bocken, C. Schuit, C. Kraaijenhagen, Experimenting with a circular business model: lessons from eight cases, Environ. Innov. Soc. Transit. 28 (2018) 79–95, https://doi.org/10.1016/j.eist.2018.02.001.
[8] L. Li, H. Msaad, H. Sun, M. Tan, Y. Lu, A. Lau, Green innovation and business sustainability: new evidence from energy intensive industry in china, Int. J. Environ. Res. Public Health 17 (21) (2020) 7826, https://doi.org/10.3390/ijerph17217826.
[9] İ. Şener, M. Artar, How green strategy research is evolving a systematic literature review, J. Glob. Strat. Manage. (2024), https://doi.org/10.20460/jgsm.2023.317.
[10] Hao Tan, Jialing Li, Min He, Jiayu Li, Dan Zhi, Fanzhi Qin, Chen Zhang, Global evolution of research on green energy and environmental technologies:a bibliometric study, J. Environ. Manage (2021) 297, https://doi.org/10.1016/j.jenvman.2021.113382.
[11] Yong Qin, Zeshui Xu, Xinxin Wang, Marinko Škare, Green energy adoption and its determinants: a bibliometric analysis, Renew. Sustain. Energy Rev. (2022) 153, https://doi.org/10.1016/j.rser.2021.111780.
[12] M. Li, X. Wang, Z. Wang, B. Maqbool, A. Hussain, W.A. Khan, Bibliometric analysis of the research on the impact of environmental regulation on green technology innovation based on CiteSpace, Int. J. Environ. Res. Public Health (2022) 19, https://doi.org/10.3390/ijerph192013273.
[13] N. Niknejad, B. Nazari, S. Foroutani, et al., A bibliometric analysis of green technologies applied to water and wastewater treatment, Environ. Sci. Pollut. Res. 30 (2023) 71849–71863, https://doi.org/10.1007/s11356-022-18705-1.
[14] F. Belussi, L. Orsi, M. Savarese, Mapping business model research: a document bibliometric analysis, Scand. J. Manage. 35 (3) (2019) 101048, https://doi.org/10.1016/j.scaman.2019.101048.
[15] S. Goyal, S. Chauhan, P. Mishra, Circular economy research: a bibliometric analysis (2000–2019) and future research insights, J. Clean. Prod. 287 (2021) 125011, https://doi.org/10.1016/j.jclepro.2020.125011.
[16] L. Pan, Z. Xu, M. Skare, Sustainable business model innovation literature: a bibliometrics analysis, Rev. Managerial Sci. 17 (3) (2023) 757–785, https://doi.org/10.1007/s11846-022-00548-2.
[17] I.G.A.A.P. Dewi, N.N.K. Krisnawijaya, P.I. Yunita, P.D.P. Korry, Green technology for business: a bibliometric analysis, Binus Bus. Rev. 13 (2) (2022) 133–145, https://doi.org/10.21512/bbr.v13i2.7950.
[18] M.E. Porter, Essay, Sci. Am. 264 (4) (1991) 168.
[19] M.E. Porter, C. Van der Linde, Toward a new conception of the environment-competitiveness relationship, J. Econ. Perspect. 9 (4) (1995) 97–118, https://doi.org/10.1257/jep.9.4.97.
[20] Stefan & Ambec, Paul. Lanoie, Does it pay to be green? A systematic overview, Acad. Manage. Perspect. 22 (2008) 45–62, https://doi.org/10.5465/AMP.2008.35590353.
[21] A. Jaffe, R. Stavins, Dynamic incentives of environmental regulations: the effects of alternative policy instruments on technology diffusion, J. Environ. Econ. Manage 29 (3) (1995) S43–S63, https://doi.org/10.1006/jeem.1995.1060.
[22] K. Rennings, Redefining innovation — Eco-innovation research and the contribution from ecological economics, Ecol. Econ. 32 (2) (2000) 319–332, https://doi.org/10.1016/S0921-8009(99)00112-3.
[23] J. Horbach, C. Rammer, K. Rennings, Determinants of eco-innovations by type of environmental impact — The role of regulatory push/pull, technology push and market pull, Ecol. Econ. 78 (C) (2012) 112–122. https://EconPapers.repec.org/RePEc:eee:ecolec:v:78:y:2012:i:c:p:112-122.
[24] M. Geissdoerfer, P. Savaget, N.M. Bocken, E.J. Hultink, The Circular Economy – A new sustainability paradigm? J. Clean. Prod. 143 (2017) 757–768, https://doi.org/10.1016/j.jclepro.2016.12.048.
[25] S. Borghesi, G. Cainelli, M. Mazzanti, Linking emission trading to environmental innovation: evidence from the Italian manufacturing industry, Res. Policy 44 (3) (2015) 669–683.
[26] Sanya Carley, David. Konisky, The justice and equity implications of the clean energy transition, Nat. Energy 5 (2020), https://doi.org/10.1038/s41560-020-0641-6.
[27] C.P. Kiefer, P.D. Río González, J. Carrillo-Hermosilla, Drivers and barriers of eco-innovation types for sustainable transitions: a quantitative perspective, Bus. Strat.. Environ. 28 (1) (2018) 155–172, https://doi.org/10.1002/bse.2246.
[28] Y.S. Chen, The positive effect of green intellectual capital on competitive advantages of firms, J. Bus. Ethics 77 (2008) 271–286, https://doi.org/10.1007/s10551-006-9349-1.
[29] W.M. Cohen, D.A. Levinthal, Absorptive capacity: a new perspective on learning and innovation, Adm. Sci. Q. 35 (1) (1990) 128–152, https://doi.org/10.2307/2393553.
[30] P. Del Río González, The empirical analysis of the determinants for environmental technological change: a research agenda, Ecol. Econ. 68 (3) (2009) 861–878, https://doi.org/10.1016/j.ecolecon.2008.07.004.
[31] L. Wang, Y. Wu, Z. Huang, Y. Wang, How big data drives green economic development: evidence from China, Front. Environ. Sci. 10 (2022) 1055162, https://doi.org/10.3389/fenvs.2022.1055162.
[32] C. Zott, R. Amit, Business model design: an activity system perspective, Long. Range Plann. 43 (2–3) (2010) 216–226, https://doi.org/10.1016/j.lrp.2009.07.004.
[33] A. Joyce, R.L. Paquin, The triple layered business model canvas: a tool to design more sustainable business models, J. Clean. Prod. 135 (2016) 1474–1486, https://doi.org/10.1016/j.jclepro.2016.06.067.
[34] A. Daou, C. Mallat, G. Chammas, N. Cerantola, S. Kayed, N.A. Saliba, The Ecocanvas as a business model canvas for a circular economy, J. Clean. Prod. 258 (2020) 120938, https://doi.org/10.1016/j.jclepro.2020.120938.
[35] R. Pavesi, L. Orsi, L. Zanderighi, Enhancing circularity in urban waste management: a case study on biochar from urban pruning, Environments. 12 (1) (2024) 5, https://doi.org/10.3390/environments12010005.
[36] A.W. Harzing, S. Alakangas, Google Scholar, Scopus and the Web of Science: a longitudinal and cross-disciplinary comparison, Scientometrics. 106 (2016) 787–804, https://doi.org/10.1007/s11192-015-1798-9.
[37] C. Birkle, D.A. Pendlebury, J. Schnell, J. Adams, Web of Science as a data source for research on scientific and scholarly activity, Quant. Sci. Stud. 1 (1) (2020) 363–376, https://doi.org/10.1162/qss_a_00018.
[38] V.K. Singh, P. Singh, M. Karmakar, et al., The journal coverage of Web of Science, Scopus and dimensions: a comparative analysis, Scientometrics. 126 (2021) 5113–5142, https://doi.org/10.1007/s11192-021-03948-5.
[39] M. Aria, C. Cuccurullo, bibliometrix: an R-tool for comprehensive science mapping analysis, J. Informetr. 11 (4) (2017) 959–975, https://doi.org/10.1016/j.joi.2017.08.007.
[40] M.E. Falagas, E.I. Pitsouni, G.A. Malietzis, G. Pappas, Comparison of PubMed, Scopus, Web of Science, and Google Scholar: strengths and weaknesses, FASEB J.: Off. Publ. Feder. Am. Soc. Experim. Biol. 22 (2) (2008) 338–342, https://doi.org/10.1096/fj.07-9492LSF.
[41] L. Leydesdorff, S. Carley, I. Rafols, Global maps of science based on the new Web-of-Science categories, Scientometrics 94 (2013) 589–593.
[42] E. Delgado-López-Cózar, N. Robinson-García, D. Torres-Salinas, The Google scholar experiment: how to index false papers and manipulate bibliometric indicators, J. Assoc. Inf. Sci. Technol. 65 (3) (2014) 446–454, https://doi.org/10.1002/asi.23056.
[43] D. Fiala, G. Tutoky, PageRank-based prediction of award-winning researchers and the impact of citations, J. Informetr. 11 (4) (2017) 1044–1068, https://doi.org/10.1016/j.joi.2017.09.008.
[44] H. Gurzki, D.M. Woisetschläger, Mapping the luxury research landscape: a bibliometric citation analysis, J. Bus. Res. 77 (2017) 147–166, https://doi.org/10.1016/j.jbusres.2016.11.009.
[45] S.L. Hart, Beyond greening: strategies for a sustainable world, Harv. Bus. Rev. (1997). https://hbr.org/1997/01/beyond-greening-strategies-for-a-sustainable-world.
[46] T.Y. Ebrahim, Clean and sustainable technology innovation, Curr. Opin. Environ. Sustain. 45 (2020) 113–117, https://doi.org/10.1016/j.cosust.2020.11.004.

[47] I. Mignon, A. Bankel, Sustainable business models and innovation strategies to realize them: a review of 87 empirical cases, Bus. Strategy Environ. 32 (4) (2023) 1357–1372.
[48] X. Guo, A bibliometric analysis of child language during 1900–2021, Front. Psychol. 13 (2022), https://doi.org/10.3389/fpsyg.2022.862042.
[49] M. Kabil, S. Priatmoko, R. Magda, L.D. Dávid, Blue economy and coastal tourism: a comprehensive visualization bibliometric analysis, Sustainability. 13 (7) (2021) 3650, https://doi.org/10.3390/su13073650.
[50] R. Pranckutė, Web of science (wos) and scopus: the titans of bibliographic information in today's academic world, Publications 9 (1) (2021) 12, https://doi.org/10.3390/publications9010012.
[51] A.R. Hevner, S.T. March, J. Park, S. Ram, Design science in information systems research, Mis Quart. 28 (1) (2004) 75–105, https://doi.org/10.2307/25148625.
[52] M. Linnenluecke, M. Marrone, A. Singh, Conducting systematic literature reviews and bibliometric analyses, Austral. J. Manage. 45 (2) (2019) 175–194, https://doi.org/10.1177/0312896219877678.
[53] K.W. Boyack, R. Klavans, Co-citation analysis, bibliographic coupling, and direct citation: which citation approach represents the research front most accurately? J. Assoc. Inf. Sci. Technol. 61 (12) (2010) 2389–2404, https://doi.org/10.1002/asi.21419.
[54] F.P. Appio, F. Cesaroni, A. Di Minin, Visualizing the structure and bridges of the intellectual property management and strategy literature: a document co-citation analysis, Scientometrics. 101 (1) (2014) 623–661, https://doi.org/10.1007/s11192-014-1329-0.
[55] G.J. Holton, Einstein, History, and Other Passions: The Rebellion Against Science At the End of the Twentieth Century, Harvard University Press, USA, 2000.
[56] U. Sandström, Combining curriculum vitae and bibliometric analysis: mobility, gender and research performance, Res. Eval. 18 (2) (2009) 135–142, https://doi.org/10.3152/095820209X441790.
[57] E. Garfield, Announcing the SCI compact disk edition: cD-ROM-cd-rom gigabyte storage technology, novel software, and bibliographic coupling make desk-top research and discovery a reality, Curr. Contents 22 (1988) 3–13.
[58] H. Small, Visualizing science by citation mapping, J. Am. Soc. Inf. Sci. 50 (9) (1999) 799–813, https://doi.org/10.1002/(SICI)1097-4571(1999)50:9%3C799::AID-ASI9%3E3.0.CO;2-G.
[59] R. Vogel, W.H. Güttel, The dynamic capability view in strategic management: a bibliometric review, Int. J. Manage. Rev. 15 (4) (2013) 426–446, https://doi.org/10.1111/ijmr.12000.
[60] M. Sedighi, Application of word co-occurrence analysis method in mapping of the scientific fields (case study: the field of Informetrics), Libr. Rev. 65 (1/2) (2016) 52–64, https://doi.org/10.1108/LR-07-2015-0075.
[61] N.J. Van Eck, L. Waltman, Software survey: vOSviewer, a computer program for bibliometric mapping, Scientometrics. 84 (2) (2010) 523–538, https://doi.org/10.1007/s11192-009-0146-3.
[62] P. Walsh, E. Murphy, D. Horan, The role of science, technology and innovation in the UN 2030 agenda, Technol. Forecast. Soc. Change 154 (2020) 119957, https://doi.org/10.1016/j.techfore.2020.119957.
[63] M. Jakučionytė-Skodienė, G. Liobikienė, The changes in climate change concern, responsibility assumption and impact on climate-friendly behaviour in EU from the Paris agreement until 2019, Environ. Manag. 69 (1) (2022) 1–16.
[64] J.A. McNeely, Nature and COVID-19: the pandemic, the environment, and the way ahead, Ambio 50 (2021) 767–781, https://doi.org/10.1007/s13280-020-01447-0.
[65] R. Kemp, J. Schot, R. Hoogma, Regime shifts to sustainability through processes of niche formation: the approach of strategic niche management, Technol. Anal. Strateg. Manage 10 (2) (1998) 175–195, https://doi.org/10.1080/09537329808524310.
[66] R. Bohnsack, J. Pinkse, A. Kolk, Business models for sustainable technologies: exploring business model evolution in the case of electric vehicles, Res. Policy. 43 (2) (2014) 284–300, https://doi.org/10.1016/j.respol.2013.10.014.
[67] Y. Deng, D. You, J. Wang, Optimal strategy for enterprises' green technology innovation from the perspective of political competition, J. Clean. Prod. 235 (2019) 930–942, https://doi.org/10.1016/j.jclepro.2019.06.248.
[68] U. Mishra, J. Wu, B. Sarkar, A sustainable production-inventory model for a controllable carbon emissions rate under shortages, J. Clean. Prod. 256 (2020) 120268, https://doi.org/10.1016/j.jclepro.2020.120268.
[69] C. Montalvo, General wisdom concerning the factors affecting the adoption of cleaner technologies: a survey 1990–2007, J. Clean. Prod. 16 (1) (2007) S7–S13, https://doi.org/10.1016/j.jclepro.2007.10.002.
[70] Y. Fernando, C.J. Chiappetta Jabbour, W. Wah, Pursuing green growth in technology firms through the connections between environmental innovation and sustainable business performance: does service capability matter? Resour., Conserv. Recycl. 141 (2019) 8–20, https://doi.org/10.1016/j.resconrec.2018.09.031.
[71] Q. Luo, C. Miao, L. Sun, X. Meng, M. Duan, Efficiency evaluation of green technology innovation of China's strategic emerging industries: an empirical analysis based on Malmquist-data envelopment analysis index, J. Clean. Prod. 238 (2019) 117782, https://doi.org/10.1016/j.jclepro.2019.117782.
[72] L. Sun, C. Miao, L. Yang, Ecological-economic efficiency evaluation of green technology innovation in strategic emerging industries based on entropy weighted TOPSIS method, Ecol. Indic. 73 (2017) 554–558, https://doi.org/10.1016/j.ecolind.2016.10.018.
[73] Y. Ma, Q. Zhang, Q. Yin, Top management team faultlines, green technology innovation and firm financial performance, J. Environ. Manage 285 (2021) 112095, https://doi.org/10.1016/j.jenvman.2021.112095.
[74] C. Chen, CiteSpace II: detecting and visualizing emerging trends and transient patterns in scientific literature, J. Assoc. Inf. Sci. Technol. 57 (3) (2006) 359–377, https://doi.org/10.1002/asi.20317.
[75] L. Waltman, N.J. van Eck, Source normalized indicators of citation impact: an overview of different approaches and an empirical comparison, Scientometrics. 96 (3) (2013) 699–716, https://doi.org/10.1007/s11192-012-0913-4.
[76] Y. Wu, H. Wang, Z. Wang, B. Zhang, B.C. Meyer, Knowledge mapping analysis of rural landscape using CiteSpace, Sustainability. 12 (1) (2019) 66, https://doi.org/10.3390/su12010066.
[77] N.J. Van Eck, L. Waltman, How to normalize cooccurrence data? An analysis of some well-known similarity measures, J. Am. Soc. Inf. Sci. Technol. 60 (8) (2009) 1635–1651, https://doi.org/10.1002/asi.21075.
[78] D. Krass, T. Nedorezov, A. Ovchinnikov, Environmental taxes and the choice of green technology, Prod. Oper. Manage 22 (5) (2013) 1035–1055, https://doi.org/10.1111/poms.12023.
[79] Z. Hong, X. Guo, Green product supply chain contracts considering environmental responsibilities, Omega (Westport) 83 (2019) 155–166, https://doi.org/10.1016/j.omega.2018.02.010.
[80] D. Ghosh, J. Shah, Supply chain analysis under green sensitive consumer demand and cost sharing contract, Int. J. Prod. Econ. 164 (2015) 319–329, https://doi.org/10.1016/j.ijpe.2014.11.005.
[81] Z. Liu, T.D. Anderson, J.M. Cruz, Consumer environmental awareness and competition in two-stage supply chains, Eur. J. Oper. Res. 218 (3) (2012) 602–613, https://doi.org/10.1016/j.ejor.2011.11.027.
[82] G. Bi, M. Jin, L. Ling, et al., Environmental subsidy and the choice of green technology in the presence of green consumers, Ann. Oper. Res. 255 (2017) 547–568, https://doi.org/10.1007/s10479-016-2106-7.
[83] M.C. Cohen, R. Lobel, G. Perakis, The impact of demand uncertainty on consumer subsidies for green technology adoption, Manage Sci. 62 (5) (2016) 1225–1531, https://doi.org/10.1287/mnsc.2015.2173.
[84] X. Xie, J. Huo, H. Zou, Green process innovation, green product innovation, and corporate financial performance: a content analysis method, J. Bus. Res. 101 (2019) 697–706, https://doi.org/10.1016/j.jbusres.2019.01.010.
[85] K. Du, Y. Cheng, X. Yao, Environmental regulation, green technology innovation, and industrial structure upgrading: the road to the green transformation of Chinese cities, Energy Econ. 98 (2021) 105247, https://doi.org/10.1016/j.eneco.2021.105247.
[86] C. Lv, C. Shao, C. Lee, Green technology innovation and financial development: do environmental regulation and innovation output matter? Energy Econ. 98 (2021) 105237 https://doi.org/10.1016/j.eneco.2021.105237.
[87] X. Cai, B. Zhu, H. Zhang, L. Li, M. Xie, Can direct environmental regulation promote green technology innovation in heavily polluting industries? Evidence from Chinese listed companies, Sci. Total Environ. 746 (2020) 140810.
[88] K. Du, P. Li, Z. Yan, Do green technology innovations contribute to carbon dioxide emission reduction? Empirical evidence from patent data, Technol. Forecast. Soc. Change 146 (2019) 297–303, https://doi.org/10.1016/j.techfore.2019.06.010.
[89] A. Jaffe, K. Palmer, Environmental Regulation and Innovation: a panel data study, Rev. Econ. Stat. 79 (4) (1997) 610–619, https://doi.org/10.1162/003465397557196.
[90] J. Horbach, Determinants of environmental innovation—New evidence from German panel data sources, Res. Policy. 37 (1) (2008) 163–173, https://doi.org/10.1016/j.respol.2007.08.006.
[91] D. Acemoglu, P. Aghion, L. Bursztyn, D. Hemous, The environment and directed technical change, Am. Econ. Rev. 102 (1) (2012) 131–166, https://doi.org/10.1257/aer.102.1.131.
[92] F. Boons, F. Lüdeke-Freund, Business models for sustainable innovation: state-of-the-art and steps towards a research agenda, J. Clean. Prod. 45 (2013) 9–19, https://doi.org/10.1016/j.jclepro.2012.07.007.
[93] N. Bocken, S. Short, P. Rana, S. Evans, A literature and practice review to develop sustainable business model archetypes, J. Clean. Prod. 65 (2014) 42–56, https://doi.org/10.1016/j.jclepro.2013.11.039.
[94] K. Hockerts, R. Wüstenhagen, Greening Goliaths versus emerging Davids — Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship, J. Bus. Ventur. 25 (5) (2010) 481–492, https://doi.org/10.1016/j.jbusvent.2009.07.005.
[95] S. Schaltegger, F. Lüdeke-Freund, E.G. Hansen, Business cases for sustainability: the role of business model innovation for corporate sustainability, Int. J. Innov. Sustain. Dev. 6 (2) (2012) 95–119, https://doi.org/10.1504/IJISD.2012.046944.
[96] D.J. Teece, Business models, Business strategy and innovation, Long Range Plann. 43 (2–3) (2010) 172–194, https://doi.org/10.1016/j.lrp.2009.07.003.
[97] M. Hekkert, R. Suurs, S. Negro, S. Kuhlmann, R. Smits, Functions of innovation systems: a new approach for analysing technological change, Technol. Forecast. Soc. Change 74 (4) (2007) 413–432, https://doi.org/10.1016/j.techfore.2006.03.002.
[98] S.L. Hart, A natural-resource-based view of the firm, Acad. Manage. Rev. 20 (4) (1995) 986–1014, https://doi.org/10.2307/258963.
[99] Y. Chen, S.B. Lai, C.T. Wen, The influence of green innovation performance on corporate advantage in Taiwan, J. Bus. Ethics 67 (2006) 331–339, https://doi.org/10.1007/s10551-006-9025-5.
[100] S. Sharma, H. Vredenburg, Proactive corporate environmental strategy and the development of competitively valuable organizational capabilities, Strateg. Manage J. 19 (8) (1998) 729–753, https://doi.org/10.1002/(SICI)1097-0266(199808)19:8<729::AID-SMJ967>3.0.CO;2-4.
[101] J. Barney, Firm resources and sustained competitive advantage, J. Manage (1991), https://doi.org/10.1177/014920639101700108.

[102] D.J. Teece, G. Pisano, A. Shuen, Dynamic capabilities and strategic management, Strateg. Manage J. 18 (7) (1997) 509–533, https://doi.org/10.1002/(SICI)1097-0266(199708)18:7≤509::AID-SMJ882≥3.0.CO;2-Z.
[103] C. Fornell, D.F. Larcker, Evaluating structural equation models with unobservable variables and measurement error, J. Market. Res. 18 (1) (1981) 39–50, https://doi.org/10.2307/3151312.
[104] P.M. Podsakoff, S.B. MacKenzie, J.-Y. Lee, N.P. Podsakoff, Common method biases in behavioral research: a critical review of the literature and recommended remedies, J. Appl. Psychol. 88 (5) (2003) 879–903, https://doi.org/10.1037/0021-9010.88.5.879.
[105] P. Berrone, A. Fosfuri, L. Gelabert, L.R. Gomez-Mejia, Necessity as the mother of 'green' inventions: institutional pressures and environmental innovations, Strateg. Manage J. 34 (8) (2013) 891–909, https://doi.org/10.1002/smj.2041.
[106] M.V. Russo, P.A. Fouts, A resource-based perspective on corporate environmental performance and profitability, Acad. Manage. J. 40 (1997) 534–559, https://doi.org/10.2307/257052.
[107] A. Phdungsilp, Futures studies' backcasting method used for strategic sustainable city planning, Futures. 43 (7) (2011) 707–714, https://doi.org/10.1016/j.futures.2011.05.012.
[108] R. Xie, T.S. Teo, Green technology innovation, environmental externality, and the cleaner upgrading of industrial structure in China — Considering the moderating effect of environmental regulation, Technol. Forecast. Soc. Change 184 (2022) 122020, https://doi.org/10.1016/j.techfore.2022.122020.
[109] Z. Yang, H. Chen, L. Du, C. Lin, W. Lu, How does alliance-based government-university-industry foster cleantech innovation in a green innovation ecosystem? J. Clean. Prod. 283 (2021) 124559 https://doi.org/10.1016/j.jclepro.2020.124559.
[110] Z. Li, Z. Huang, Y. Su, New media environment, environmental regulation and corporate green technology innovation:evidence from China, Energy Econ. 119 (2023) 106545, https://doi.org/10.1016/j.eneco.2023.106545.
[111] V. Costantini, F. Crespi, G. Marin, E. Paglialunga, Eco-innovation, sustainable supply chains and environmental performance in European industries, J. Clean. Prod. 155 (2017) 141–154, https://doi.org/10.1016/j.jclepro.2016.09.038.
[112] C.I. Fernandes, P.M. Veiga, J.M. Ferreira, M. Hughes, Green growth versus economic growth: do sustainable technology transfer and innovations lead to an imperfect choice? Bus. Strategy. Environ. 30 (4) (2021) 2021–2037, https://doi.org/10.1002/bse.2730.
[113] B. Orlando, L.V. Ballestra, V. Scuotto, M. Pironti, M. Di Giudice, The impact of R&D investments on eco-innovation: a cross-cultural perspective of green technology management, IEEe Trans. Eng. Manage 69 (5) (2022) 2275–2284, https://doi.org/10.1109/TEM.2020.3005525.
[114] G. Lian, A. Xu, Y. Zhu, Substantive green innovation or symbolic green innovation? The impact of ER on enterprise green innovation based on the dual moderating effects, J. Innov. Knowl. 7 (3) (2022) 100203, https://doi.org/10.1016/j.jik.2022.100203.
[115] C. Tang, Y. Xu, Y. Hao, H. Wu, Y. Xue, What is the role of telecommunications infrastructure construction in green technology innovation? A firm-level analysis for China, Energy Econ. 103 (2021) 105576, https://doi.org/10.1016/j.eneco.2021.105576.
[116] F. Zhou, X. Wang, The carbon emissions trading scheme and green technology innovation in China: a new structural economics perspective, Econ. Anal. Policy. 74 (2022) 365–381, https://doi.org/10.1016/j.eap.2022.03.007.
[117] X. Zhou, J. Du, Does environmental regulation induce improved financial development for green technological innovation in China? J. Environ. Manage 300 (2021) 113685 https://doi.org/10.1016/j.jenvman.2021.113685.
[118] A. Xu, Y. Zhu, W. Wang, Micro green technology innovation effects of green finance pilot policy—From the perspectives of action points and green value, J. Bus. Res. 159 (2023) 113724, https://doi.org/10.1016/j.jbusres.2023.113724.
[119] M. Ikram, R. Sroufe, U. Awan, N. Abid, Enabling progress in developing economies: a novel hybrid decision-making model for green technology planning, Sustainability. 14 (1) (2021) 258, https://doi.org/10.3390/su14010258.
[120] Z. Luo, X. Chen, X. Wang, The role of co-opetition in low carbon manufacturing, Eur. J. Oper. Res. 253 (2) (2016) 392–403, https://doi.org/10.1016/j.ejor.2016.02.030.
[121] U. Mishra, J. Wu, B. Sarkar, Optimum sustainable inventory management with backorder and deterioration under controllable carbon emissions, J. Clean. Prod. 279 (2021) 123699, https://doi.org/10.1016/j.jclepro.2020.123699.
[122] C. Lu, C. Yang, H. Yen, Stackelberg game approach for sustainable production-inventory model with collaborative investment in technology for reducing carbon emissions, J. Clean. Prod. 270 (2020) 121963, https://doi.org/10.1016/j.jclepro.2020.121963.
[123] S. Ma, Y. He, R. Gu, S. Li, Sustainable supply chain management considering technology investments and government intervention, Transp. Res. Part E: Logist. Transp. Rev. 149 (2021) 102290, https://doi.org/10.1016/j.tre.2021.102290.
[124] A.H.M. Mashud, D. Roy, Y. Daryanto, R.K. Chakrabortty, M. Tseng, A sustainable inventory model with controllable carbon emissions, deterioration and advance payments, J. Clean. Prod. 296 (2021) 126608, https://doi.org/10.1016/j.jclepro.2021.126608.
[125] A.H. Mashud, M. Pervin, U. Mishra, Y. Daryanto, M. Tseng, M.K. Lim, A sustainable inventory model with controllable carbon emissions in green-warehouse farms, J. Clean. Prod. 298 (2021) 126777, https://doi.org/10.1016/j.jclepro.2021.126777.
[126] X. Chen, Z. Luo, X. Wang, Impact of efficiency, investment, and competition on low carbon manufacturing, J. Clean. Prod. 143 (2017) 388–400, https://doi.org/10.1016/j.jclepro.2016.12.095.
[127] G. Dou, T. Choi, Does implementing trade-in and green technology together benefit the environment? Eur. J. Oper. Res. 295 (2) (2021) 517–533, https://doi.org/10.1016/j.ejor.2021.03.017.
[128] X. Wang, S.-H. Cho, A. Scheller-Wolf, Green technology development and adoption: competition, regulation, and uncertainty—A global game approach, Manage Sci. 67 (1) (2020) 201–219, https://doi.org/10.1287/mnsc.2019.3538.
[129] W. Yang, Y. Pan, J. Ma, T. Yang, X. Ke, Effects of allowance allocation rules on green technology investment and product pricing under the cap-and-trade mechanism, Energy Policy 139 (2020) 111333, https://doi.org/10.1016/j.enpol.2020.111333.
[130] W. Zhang, M. Zhang, S. Wu, F. Liu, A complex path model for low-carbon sustainable development of enterprise based on system dynamics, J. Clean. Prod. 321 (2021) 128934, https://doi.org/10.1016/j.jclepro.2021.128934.
[131] J. Abbas, M. Sağsan, Impact of knowledge management practices on green innovation and corporate sustainable development: a structural analysis, J. Clean. Prod. 229 (2019) 611–620, https://doi.org/10.1016/j.jclepro.2019.05.024.
[132] S. Sahoo, A. Kumar, A. Upadhyay, How do green knowledge management and green technology innovation impact corporate environmental performance? Understanding the role of green knowledge acquisition, Bus. Strat. Environ. 32 (1) (2022) 551–569, https://doi.org/10.1002/bse.3160.
[133] K.V. Bhupendra, S. Sangle, Strategy to derive benefits of radical cleaner production, products and technologies: a study of Indian firms, J. Clean. Prod. 126 (2016) 236–247, https://doi.org/10.1016/j.jclepro.2016.03.115.
[134] K.V. Bhupendra, S. Sangle, What drives successful implementation of pollution prevention and cleaner technology strategy? The role of innovative capability, J. Environ. Manage 155 (2015) 184–192, https://doi.org/10.1016/j.jenvman.2015.03.032.
[135] S.J. Khan, P. Kaur, F. Jabeen, A. Dhir, Green process innovation: where we are and where we are going, Bus. Strategy. Environ. 30 (7) (2021) 3273–3296, https://doi.org/10.1002/bse.2802.
[136] C.M. De Stefano, M.J. Montes-Sancho, T. Busch, A natural resource-based view of climate change: innovation challenges in the automobile industry, J. Clean. Prod. 139 (2016) 1436–1448, https://doi.org/10.1016/j.jclepro.2016.08.023.
[137] P. Yacob, L.S. Wong, S.C. Khor, An empirical investigation of green initiatives and environmental sustainability for manufacturing SMEs, J. Manuf. Technol. Manage. 30 (1) (2019) 2–25, https://doi.org/10.1108/JMTM-08-2017-0153.
[138] G. Qi, Y. Jia, H. Zou, Is institutional pressure the mother of green innovation? Examining the moderating effect of absorptive capacity, J. Clean. Prod. 278 (2020) 123957, https://doi.org/10.1016/j.jclepro.2020.123957.
[139] B. Wu, A. Monfort, C. Jin, X. Shen, Substantial response or impression management? Compliance strategies for sustainable development responsibility in family firms, Technol. Forecast. Soc. Change 174 (2021) 121214, https://doi.org/10.1016/j.techfore.2021.121214.
[140] R.M. Dangelico, P. Pontrandolfo, D. Pujari, Developing sustainable new products in the textile and upholstered furniture industries: role of external integrative capabilities, J. Prod. Innov. Manage. 30 (4) (2013) 642–658, https://doi.org/10.1111/jpim.12013.
[141] H. Kim, Deregulation and differentiation: incumbent investment in green technologies, Strateg. Manage J. 34 (10) (2013) 1162–1185, https://doi.org/10.1002/smj.2067.
[142] C. Weigelt, E. Shittu, Competition, regulatory policy, and firms' Resource investments: the case of renewable energy technologies, Acad. Manage. J. 59 (2) (2015), https://doi.org/10.5465/amj.2013.0661.
[143] J.A. Aragon-Correa, D.I. Leyva-de la Hiz, The influence of technology differences on corporate environmental patents: a resource-based versus an institutional view of green innovations, Bus. Strategy. Environ. 25 (6) (2016) 421–434, https://doi.org/10.1002/bse.1885.
[144] M. Meyskens, A.L. Carsrud, Nascent green-technology ventures: a study assessing the role of partnership diversity in firm success, Small Bus. Econ. 40 (2013) 739–759, https://doi.org/10.1007/s11187-011-9400-1.
[145] D. Xia, M. Zhang, Q. Yu, Y. Tu, Developing a framework to identify barriers of green technology adoption for enterprises, Resour., Conserv. Recycl. 143 (2019) 99–110, https://doi.org/10.1016/j.resconrec.2018.12.022.
[146] D. Bhandari, R.K. Singh, S.K. Garg, Prioritisation and evaluation of barriers intensity for implementation of cleaner technologies: framework for sustainable production, Resour., Conserv. Recycl. 146 (2019) 156–167, https://doi.org/10.1016/j.resconrec.2019.02.038.
[147] D. Xia, Q. Yu, Q. Gao, G. Cheng, Sustainable technology selection decision-making model for enterprise in supply chain: based on a modified strategic balanced scorecard, J. Clean. Prod. 141 (2017) 1337–1348, https://doi.org/10.1016/j.jclepro.2016.09.083.
[148] J. Ren, H. Liang, F.T. Chan, Urban sewage sludge, sustainability, and transition for Eco-City: multi-criteria sustainability assessment of technologies based on best-worst method, Technol. Forecast. Soc. Change 116 (2017) 29–39, https://doi.org/10.1016/j.techfore.2016.10.070.
[149] N. Hrovatin, N. Dolšak, J. Zorić, Factors impacting investments in energy efficiency and clean technologies: empirical evidence from Slovenian manufacturing firms, J. Clean. Prod. 127 (2016) 475–486, https://doi.org/10.1016/j.jclepro.2016.04.039.
[150] D. An, B. Xi, J. Ren, Y. Wang, X. Jia, C. He, Z. Li, Sustainability assessment of groundwater remediation technologies based on multi-criteria decision making method, Resour., Conserv. Recycl., 119 (2017) 36–46, https://doi.org/10.1016/j.resconrec.2016.08.002.
[151] M. Tseng, R.R. Tan, A.B. Siriban-Manalang, Sustainable consumption and production for Asia: sustainability through green design and practice, J. Clean. Prod. 40 (2013) 1–5, https://doi.org/10.1016/j.jclepro.2012.07.015.

[152] K.R. Vanapalli, H.B. Sharma, V.P. Ranjan, B. Samal, J. Bhattacharya, B.K. Dubey, S. Goel, Challenges and strategies for effective plastic waste management during and post COVID-19 pandemic, Sci. Total. Environ. 750 (2021) 141514, https://doi.org/10.1016/j.scitotenv.2020.141514.
[153] A. Belhadi, S.S. Kamble, S.A.R. Khan, et al., Infectious waste management strategy during COVID-19 Pandemic in Africa: an integrated decision-making framework for selecting sustainable technologies, Environ. Manage 66 (2020) 1085–1104, https://doi.org/10.1007/s00267-020-01375-5.
[154] I.S. Cruz, T. Katz-Gerro, Urban public transport companies and strategies to promote sustainable consumption practices, J. Clean. Prod. 123 (2016) 28–33, https://doi.org/10.1016/j.jclepro.2015.12.007.
[155] P.K. Tarei, P. Chand, H. Gupta, Barriers to the adoption of electric vehicles: evidence from India, J. Clean. Prod. 291 (2021) 125847, https://doi.org/10.1016/j.jclepro.2021.125847.
[156] G. Orsatti, F. Quatraro, M. Pezzoni, The antecedents of green technologies: the role of team-level recombinant capabilities, Res. Policy. 49 (3) (2020) 103919, https://doi.org/10.1016/j.respol.2019.103919.
[157] L. Coenen, F.J. Díaz López, Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities, J. Clean. Prod. 18 (12) (2010) 1149–1160, https://doi.org/10.1016/j.jclepro.2010.04.003.
[158] D. Browne, M. O'Mahony, B. Caulfield, How should barriers to alternative fuels and vehicles be classified and potential policies to promote innovative technologies be evaluated? J. Clean. Prod. 35 (2012) 140–151, https://doi.org/10.1016/j.jclepro.2012.05.019.
[159] I. Mignon, A. Bergek, System- and actor-level challenges for diffusion of renewable electricity technologies: an international comparison, J. Clean. Prod. 128 (2016) 105–115, https://doi.org/10.1016/j.jclepro.2015.09.048.
[160] J. Musiolik, J. Markard, M. Hekkert, Networks and network resources in technological innovation systems: towards a conceptual framework for system building, Technol. Forecast. Soc. Change 79 (6) (2012) 1032–1048, https://doi.org/10.1016/j.techfore.2012.01.003.
[161] P. Söderholm, H. Hellsmark, J. Frishammar, J. Hansson, J. Mossberg, A. Sandström, Technological development for sustainability: the role of network management in the innovation policy mix, Technol. Forecast. Soc. Change 138 (2018) 309–323, https://doi.org/10.1016/j.techfore.2018.10.010.
[162] J. Hall, S. Matos, S. Gold, L.S. Severino, The paradox of sustainable innovation: the 'Eroom' effect (Moore's law backwards), J. Clean. Prod. 172 (2018) 3487–3497, https://doi.org/10.1016/j.jclepro.2017.07.162.
[163] J.L. Wadin, K. Ahlgren, L. Bengtsson, Joint business model innovation for sustainable transformation of industries – A large multinational utility in alliance with a small solar energy company, J. Clean. Prod. 160 (2017) 139–150, https://doi.org/10.1016/j.jclepro.2017.03.151.
[164] S. Lubik, E. Garnsey, Early business model evolution in science-based ventures: the case of advanced materials, Long. Range Plann. 49 (3) (2016) 393–408, https://doi.org/10.1016/j.lrp.2015.03.001.
[165] H. Desing, D. Brunner, F. Takacs, S. Nahrath, K. Frankenberger, R. Hischier, A circular economy within the planetary boundaries: towards a resource-based, systemic approach, Resour., Conserv. Recycl., 155 (2020) 104673, https://doi.org/10.1016/j.resconrec.2019.104673.
[166] P.T. Lam, E.H. Chan, C. Poon, C. Chau, K. Chun, Factors affecting the implementation of green specifications in construction, J. Environ. Manage 91 (3) (2009) 654–661, https://doi.org/10.1016/j.jenvman.2009.09.029.
[167] K. Green, P. Vergragt, Towards sustainable households: a methodology for developing sustainable technological and social innovations, Futures, 34 (5) (2002) 381–400, https://doi.org/10.1016/S0016-3287(01)00066-0.
[168] C. Almeida, F. Agostinho, B. Giannetti, D. Huisingh, Integrating cleaner production into sustainability strategies: an introduction to this special volume, J. Clean. Prod. 96 (2015) 1–9, https://doi.org/10.1016/j.jclepro.2014.11.083.
[169] V. Rossa-Roccor, E.S. Acheson, F. Andrade-Rivas, M. Coombe, S. Ogura, L. Super, A. Hong, Scoping review and bibliometric analysis of the term "planetary health" in the peer-reviewed literature, Front. Public Health 8 (2020), https://doi.org/10.3389/fpubh.2020.00343.
[170] M. Anwar, T. Clauss, N. Meyer, Entrepreneurship in family firms: an updated bibliometric overview, Rev. Manage. Sci. (2023), https://doi.org/10.1007/s11846-023-00650-z.