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| RESEARCH ARTICLE

Circular Economy Metrics: A Systematic Bibliometric Mapping

Stepan Franc[1]✉ and Petra Holendova[2]
[1]PhD Candidate and Lecturer, Department of Economics, Brno University of Technology, Czech Republic
[2]PhD Candidate and Lecturer, Department of Economics, Brno University of Technology, Czech Republic
Corresponding Author: Stepan Franc, **E-mail**: Stepan.Franc@vut.cz

| ABSTRACT
The circular economy has emerged as a key concept for sustainable development, yet measurement frameworks remain inconsistent. In this bibliometric mapping, we conducted an analysis of 701 publications from Web of Science and Scopus to identify current models for evaluating circularity. Results show a concentration of research in China and Europe, with eleven thematic clusters emerging: waste management, resource efficiency, and lifecycle assessment, among others. Despite increasing attention, significant gaps remain in standardized metrics and comprehensive evaluation tools. This review highlights the need for unified methodologies to effectively assess circular economic performance across sectors and geographies.

| KEYWORDS
Benchmarking, Bibliometric analysis, Circular economy, Measurement framework, PRISMA 2020

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1. Introduction

The contents of each section may be provided to help understand the paper. The concept of the circular economy represents a fundamental shift in the approach to sustainability and environmental protection. In contrast to the traditional linear economic model defined by the "take, make, use, dispose" paradigm that contributes to the depletion of natural resources and excessive waste generation, the circular economy emphasizes the efficient use of materials and energy within closed-loop systems (Geissdoerfer et al., 2017). This approach includes strategies such as reuse, recycling, repair, remanufacturing, and redesign, all of which contribute to extending product lifecycles and minimizing environmental impacts (Kirchherr, Reike and Hekkert, 2017).

The circular economy seeks to retain the added value embedded in products for as long as possible and eliminate waste. When a product reaches the end of its life cycle, its materials remain within the economy to be reused productively, thus creating additional value (IPCC, 2014). The circular economic model is designed to be restorative and regenerative by intention. It aims to maintain products, components, and materials at their highest level of utility and value, distinguishing between technical and biological cycles. Its broader objective is to decouple global economic growth from the consumption of finite resources while simultaneously supporting key policy goals, such as fostering innovation, generating employment, and reducing environmental impacts, including greenhouse gas emissions (Mcneil-Ayuk and Jrade, 2024).

According to (Sauvé, Bernard and Sloan, 2016) the circular economy is a model of production and consumption based on closed material flows that internalize the environmental externalities associated with the extraction of primary resources and waste generation, including pollution. The circular economy can be understood as a regenerative system that minimizes resource inputs, waste, emissions, and energy leakages by slowing, closing, and narrowing material and energy loops. This interpretation emphasizes the importance of strategies such as durable design, maintenance, repair, reuse, remanufacturing, refurbishment, and recycling to achieve these objectives (Geissdoerfer et al., 2017). The circular economy is also described as an economic model in which planning, resource acquisition, production, and reprocessing are intentionally designed and managed to enhance ecosystem functionality and promote human well-being. This perspective highlights the integration of both environmental and social dimensions into the foundation of economic processes (Murray, Skene, & Haynes, 2017). Moreover, the circular economy offers significant environmental, economic, and social benefits.

The aim of this study is to explore in detail the theoretical foundations of the circular economy, including its key concepts, historical development, and fundamental pillars. The study also includes a descriptive and bibliometric analysis of the current state of scientific knowledge in this domain. This analysis is based on literature indexed in the Web of Science and Scopus databases and seeks to identify key studies, thematic directions, and gaps in existing research. Special attention is given to methods for measuring the circular economy, examining their diversity, stage of development, and practical application. The overall goal is to provide a comprehensive overview of the current body of knowledge and to propose potential directions for further research in the evaluation and implementation of circular strategies.

2. Theoretical Framework

This article presents a PRISMA-aligned bibliometric mapping of the circular economy literature. We searched Web of Science and Scopus, applied predefined inclusion and exclusion criteria, and reported the selection flow using PRISMA 2020 (Page et al., 2021; Haddaway et al., 2022). The PRISMA-aligned bibliometric mapping is a form of secondary study defined as a means of identifying, evaluating, and interpreting all available research relevant to a particular research question, topic area, or phenomenon of interest (Tranfield, Denyer and Smart, 2003). This approach ensures a transparent and reproducible process for the selection, analysis, and synthesis of existing research on a specific topic. Methodologically, the PRISMA-aligned bibliometric mapping integrates both qualitative and quantitative assessments and can be regarded as a form of content analysis.

To enable a structured and in-depth investigation, the study employed bibliometric analysis a widely recognized method for the systematic and quantitative evaluation of scientific literature. This technique facilitates the identification of dominant research trends, key authors, and thematic areas. The bibliometric analysis was conducted using data extracted from Web of Science (WoS) and Scopus, two widely acknowledged databases with extensive coverage and advanced citation tracking capabilities (Mongeon and Paul-Hus, 2016). No in-depth coding of article content or thematic synthesis was undertaken. Consequently, the findings presented here should be interpreted as reflecting meta-level patterns in the research landscape such as publication dynamics, co-authorship networks, and keyword co-occurrences, rather than substantive conclusions regarding the detailed findings of individual studies.

We performed quantitative metadata analysis with Bibliometrix (Aria and Cuccurullo, 2017) and generated bibliographic maps with VOSviewer (Waltman and van Eck, 2010). Bibliometrix was used to perform quantitative metadata analysis, while VOSviewer generated bibliographic maps that visually illustrate thematic clusters and keyword frequency. These visualizations contributed to the identification of developmental trajectories and research dynamics within the field, thereby supporting the formulation of future research questions and deepening the interdisciplinary understanding of the subject (Donthu et al., 2021).

The research process was conducted through several structured phases. Initially, a broad literature search was undertaken on the circular economy. Then, the initial data collection was followed by a descriptive analysis to evaluate the formal characteristics of the collected materials. The topic was further narrowed to focus on models and methods for measuring the circular economy, followed by a comprehensive data collection stage, where inclusion criteria were defined, and the relevant materials were identified. These were then subjected to a second round of descriptive analysis and subsequently categorized based on specific analytical dimensions. Finally, the materials were evaluated according to predefined categories, and the findings were interpreted to identify key research questions and tools for measuring circular economy performance. To ensure methodological rigor and transparency, the review process was aligned with the PRISMA 2020 guidelines (Brennan and Munn, 2021).

3. Data and Methodology

The methodological approach adopted in this study was designed to provide a clear and systematic pathway from the initial formulation of the research objective to the final bibliometric outputs. Given the increasing complexity and scope of circular economy research, particular emphasis was placed on ensuring that the data collection and processing stages were both transparent and replicable. This section therefore, outlines the procedures used for sourcing, refining, and analyzing the relevant literature. The methodological process consisted of two main phases.

The first phase focused on establishing a broad overview of the circular economy research landscape. This baseline mapping enabled the identification of overarching publication trends, influential keywords, and core thematic areas that have shaped the field over the past decade. Conducting this general analysis was essential not only for contextualizing the current state of knowledge but also for defining the analytical boundaries of the subsequent, more targeted investigation.

The second phase involved narrowing the scope toward models and methods specifically designed for measuring circular economy performance. This thematic refinement required more stringent selection criteria and the integration of data from both the Web of Science and Scopus databases. By combining these sources, the study ensured wider coverage and minimized potential indexing biases. Throughout both phases, bibliometric tools such as Bibliometrix and VOSviewer were used to extract quantitative patterns, visualize conceptual structures, and identify research clusters relevant to the study's aims.

Together, these steps form the basis of the methodological framework used in this research. The following subsection presents the results of the initial general bibliometric overview, which served as a foundation for the more focused analysis that follows.

3.1 General Bibliometric Overview of Circular Economy Literature

Type the text here. For the purposes of this article, and to ensure a structured and transparent review process, the methodology was aligned with the PRISMA 2020 guidelines (Preferred Reporting Items for Systematic Reviews and Meta-Analyses), as depicted in Figure 1 (Haddaway et al., 2022).

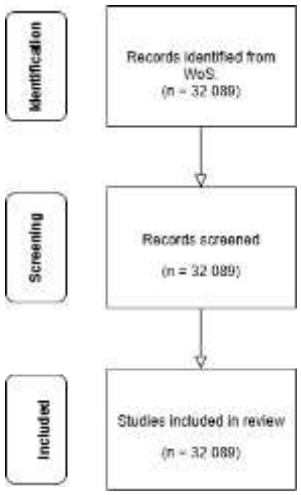

Figure 1. PRISMA 2020 for General Bibliometric Overview of Circular Economy Literature

The first step was to use the Web of Science database. From this database, the necessary sources were filtered in turn. The following steps were used for filtering:

- The topic was tagged as Circular economy (Topic)
- The years 2010 to 2024 were selected for the sake of up-to-date data. (Publication years)

After applying these criteria, publication trends were analyzed using the built-in WoS analytics tools. The results revealed a clear and steady increase in the number of publications on the circular economy, particularly after 2015, coinciding with the adoption of the Paris Agreement on climate change. Figure 2 illustrates this upward trend, highlighting the growing academic interest in this topic over the past decade. The data for the year 2024 includes publications indexed up to the last day of September.

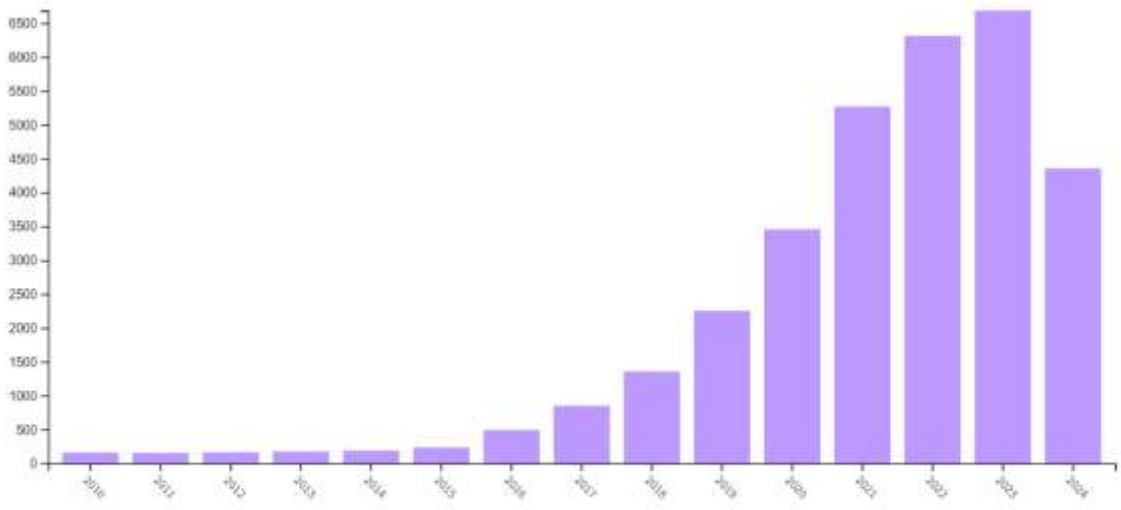

Figure 2. WoS Statistic 2010 - 2024

The next step involved exporting all filtered results from the Web of Science (32,089 records) into a format compatible with VOSviewer. The creation of a bibliographic map enabled further modifications through specific configuration options, such as

setting thresholds for the number of occurrences and other parameters Figure 3. A minimum occurrence threshold of 20 was established for keywords. Out of a total of 64,119 keywords, 744 met this threshold. For each of these 744 keywords, a relevance score was calculated, with a selection rate set at 60 %.

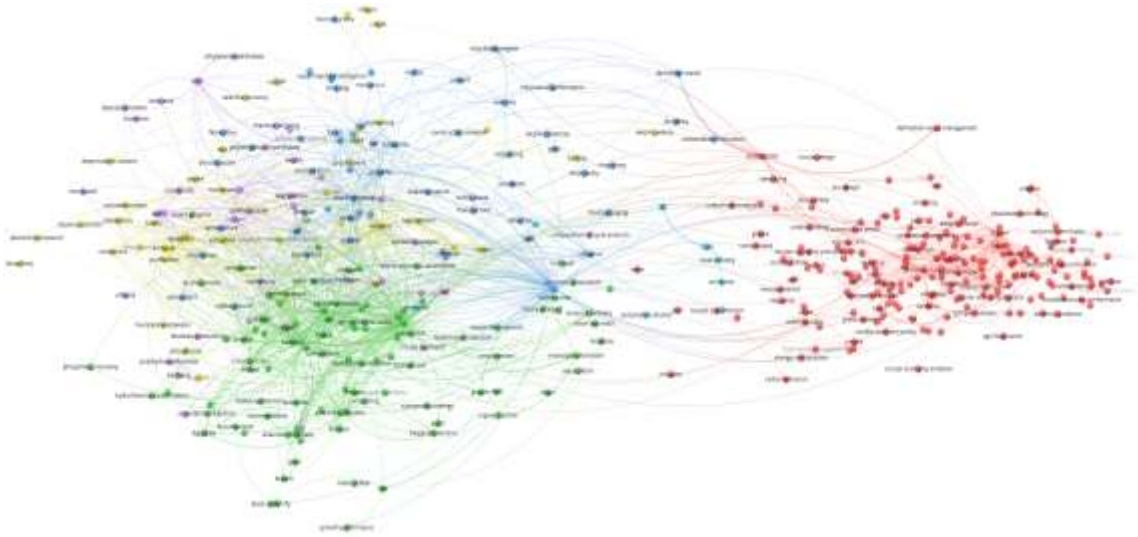

Figure 3. Results map of bibliographic analysis of general

The resulting map is made up of bubbles that are divided into "clusters" and labeled with different colors. An important factor is the distance and size of these bubbles, which determine the relationships and number of occurrences of each theme. The keywords were analyzed and divided into clusters according to the color scales. Each cluster was named based on the type of keywords contained. The total keyword analysis was divided into six clusters, including the analysis of author keywords. These clusters are presented in Tab. 1. Finally, a column was created to describe the comparison of "cluster strength" based on the number of keywords in each cluster (446 in total).

Table 1. Results of bibliographic analysis of general - clusters

Cluster	Color	Word count	Cluster strength	Identification
Cluster 1	Red	205	45.9 %	Circular economy
Cluster 2	Green	96	21.5 %	Production
Cluster 3	Blue	56	12.5 %	Effect
Cluster 4	Yellow	42	9.4 %	Recovery
Cluster 5	Purple	39	8.7 %	Synthesis
Cluster 6	Indigo	8	1.7 %	State

After completing the creation of the bibliographic map and analyzing the clusters, the 15 most important keywords were selected and analyzed in terms of their occurrence in the publications. Tab. 2, which lists the top 15 keywords by frequency, which indicates how often a keyword appears in combination with other keywords. Using this parameter, the strongest keyword is "*Circular economy*". The VOSviewer analysis also shows that the next most frequently used keyword is "*Waste*".

Table 2. Results of bibliographic analysis of general – frequency

Keywords	Frequency
Circular economy	5071
Waste	1735
Analysis	1540
Production	1389
Review	1324
Approach	1231
Industry	1217
System	1177
Application	1126
Product	1020
Case study	952
Development	938
Sustainability	911
Perspective	908
Effect	893

The total number of publications in this area is high, and it is therefore clear that this is a very promising field with room for further research. The chosen topic was further refined to include models and methods for evaluating the circular economy.

3.2 Focused Analysis: Models and Methods for Measuring Circular Economy

In the process of reviewing a refined topic, the definition of the analysis criteria is important. Thus, in the WoS and Scopus databases, the results were limited to "article". Finally, only articles written in English were selected. English was chosen as the exclusive language for the research because it is by far the most widely used in both databases and also because it is generally considered an international academic language. Both databases were queried as of 30 September 2024.

The process of data collection from relevant sources made use of the extensive Web of Science database, which offers a wide range of articles and studies from different scientific disciplines. Initially, the sources that matched the set criteria were selected and filtered from this database in a stepwise manner. This filtering process took place in several stages, during which different steps and tools were applied to narrow down the results. Each step was carefully designed to ensure that the resulting set of sources was relevant and appropriate to the desired topic. The process is presented here:

- The topic was listed as Circular economy (Topic) or (Article title, Abstract, Keywords)
- The refined topic was Models for measuring (Topic) or (Article title, Abstract, Keywords)
- Because of the current data, the years 2015 to 2024 were selected (Publication years)
- The document type was chosen to be an article (Article)
- Language set to English only (Language)

The WoS query yielded a total of 684 relevant articles, while the Scopus database returned 123 results. Both datasets were exported and merged using the RStudio statistical tool, which enabled efficient data processing and management. Following this, duplicate records, i.e., articles indexed in both databases, were identified and removed. From the initial combined total of 806 records, 105 duplicates were excluded, resulting in a final dataset of 701 unique articles for further analysis. Figure 4 illustrates this data selection process, including the application of inclusion criteria and the deduplication procedure.

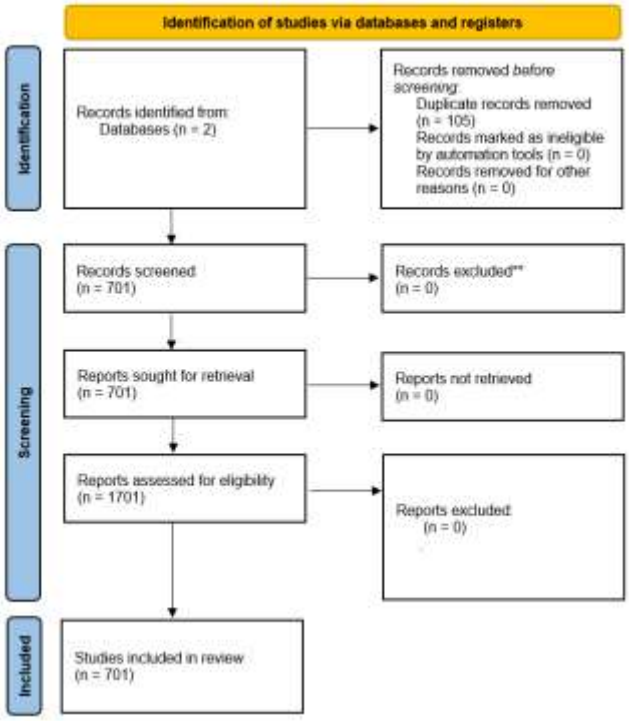

Figure 4. PRISMA 2020 Focused analysis Models and Methods for Measuring Circular Economy

Subsequently, the cleaned dataset was subjected to detailed descriptive analysis using specialized bibliometric tools, specifically Bibliometrix (R package) and VOSviewer. Following the application of predefined inclusion criteria, no full-text articles were excluded; all eligible records were retained for final analysis. These tools enabled an in-depth exploration of the scholarly landscape, including the mapping of citation networks and the identification of influential authors, core journals, and prevalent thematic areas within the field.

Tab. 3 below presents a selection of highly cited articles from the final dataset (n = 701), illustrating the diversity of approaches to circular economy measurement. Studies were selected based on citation impact and relevance to evaluation models, indicator frameworks, or lifecycle-based assessment methods.

Table 3. Overview of representative studies included in the systematic review

Author(s)	Article	Year	Country	Journal	Source	Citations	DOI
Elia, Gnoni, Tornese	Measuring circular economy strategies through index methods: A critical analysis	2017	Italy	JOURNAL OF CLEANER PRODUCTION	WoS	531	https://doi.org/10.1016/j.jclepro.2016.10.196
Ibn-Mohammed et al.	A critical analysis of the impacts of COVID-19 on the global economy and ecosystems and opportunities for circular economy strategies	2021	England	RESOURCES CONSERVATION AND RECYCLING	WoS	473	https://doi.org/10.1016/j.resconrec.2020.105169
Ranta et al.	Exploring institutional drivers and barriers of the circular economy: A cross-	2018	Finland	RESOURCES	WoS	366	https://doi.org/10.1016

	regional comparison of China, the US, and Europe			CONSERVATION AND RECYCLING			/j.resconrec.2017.08.017
Mangla et al.	Barriers to effective circular supply chain management in a developing country context	2018	England	PRODUCTION PLANNING & CONTROL	WoS	366	https://doi.org/10.1080/09537287.2018.1449265
Kazancoglu Y, Kazancoglu I, Sagnak	A new holistic conceptual framework for green supply chain management performance assessment based on circular economy	2018	Turkey	JOURNAL OF CLEANER PRODUCTION	WoS	226	https://doi.org/10.1016/j.jclepro.2018.06.015
Hao et al.	Carbon emission reduction in prefabrication construction during materialization stage: A BIM-based life-cycle assessment approach	2020	China	Science of the Total Environment	Scopus	211	https://doi.org/10.1016/j.scitotenv.2020.137870

4. Results

Descriptive analysis explored the topic of the circular economy and models for its measurement, which has become one of the key research areas within sustainable development in recent years. The aim of this analysis was to identify major trends and methodological approaches, as well as to evaluate how different countries and researchers contribute to the development of circular economy measurement frameworks. The analysis was based on data aggregated from major scientific databases and processed using advanced bibliometric and visualization tools.

The dataset was drawn from reputable databases containing a wide spectrum of peer-reviewed journals and academic publications. Among the most frequently represented journals were the Journal of Cleaner Production, Sustainability, and Resources, Conservation and Recycling, all of which serve as leading platforms for publishing research in the fields of sustainability and the circular economy. These journals play a central role in publishing research on sustainability and circular economic topics, offering a wide spectrum of theoretical and applied insights, especially on resource efficiency and waste reduction strategies. Their relevance is underlined not only by the number of published articles but also by their high citation rates, as illustrated in Figure 5, which shows the most prominent journals based on publication frequency within the selected dataset.

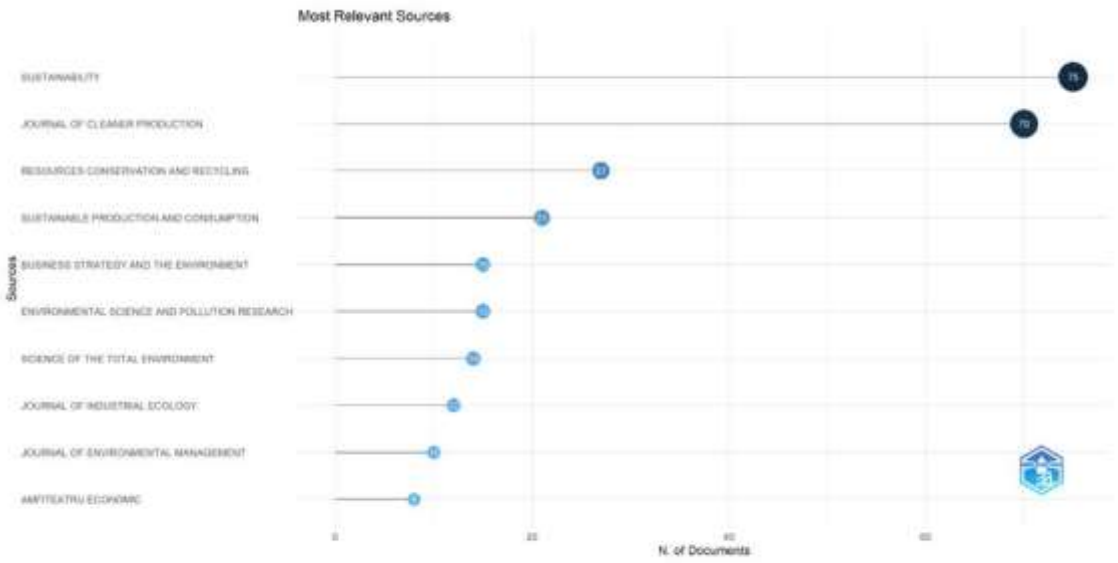

Figure 5. Most relevant sources

In terms of geographical distribution, the analysis revealed that China is the leading contributor to the field, not only due to its industrial activity but also thanks to policy-driven support for sustainability initiatives. Italy and Spain follow as significant contributors, particularly in areas related to technological innovation and recycling. This global spread of research activities is visualized in Figure 5, which maps the country's most active in publishing on the circular economy.

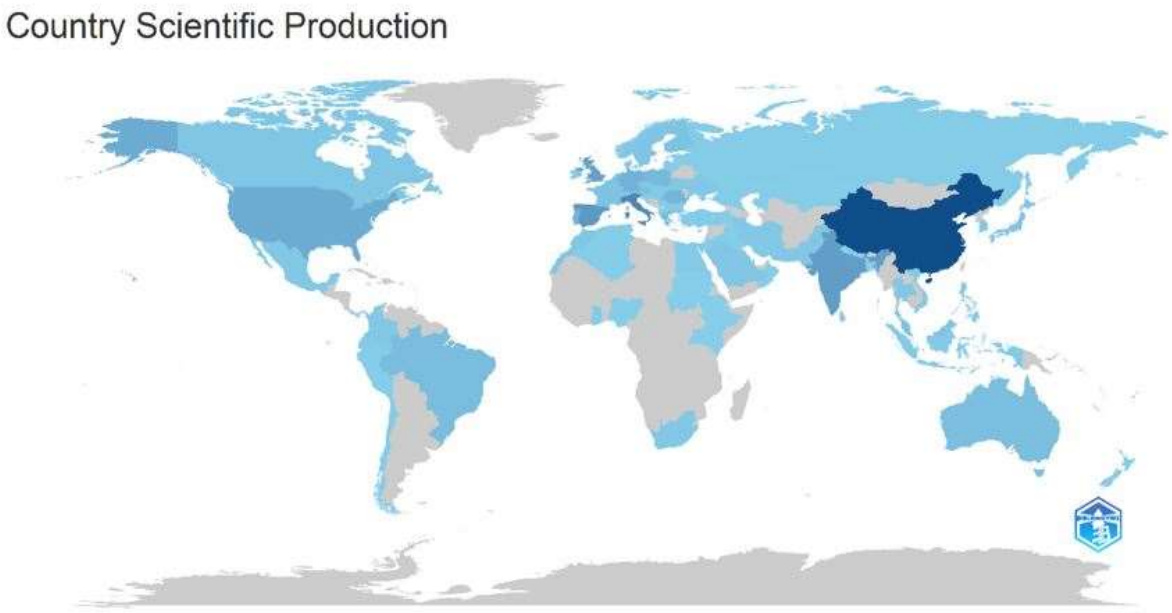

Figure 6. Country scientific production

In addition to analysing collaborative patterns, a comprehensive thematic mapping procedure was conducted to reveal the conceptual structure of the research field. Keyword co-occurrence analysis enabled the identification of recurring thematic foci as well as the intensity of their interconnections. The resulting map clearly demonstrates how individual concepts cluster together, forming coherent thematic groups that reflect the main directions of scholarly attention. The analysis shows that terms such as circular economy, resource efficiency, and waste occupy central positions in the network, both in terms of frequency and linkage strength. Their prominence indicates that debates related to sustainability, material loops, and environmental impact continue to shape the intellectual core of the field. These central themes are surrounded by a number of secondary clusters dealing, for example, with renewable materials, supply-chain management, or policy frameworks, illustrating the multi-disciplinary nature of the topic. Fig 6 visually represents this thematic structure through a color-coded cluster map. Larger bubbles correspond to more frequently occurring keywords, while shorter distances between bubbles reflect stronger co-occurrence patterns. The clustering allows for a clear interpretation of how research topics overlap and evolve, highlighting both well-established themes and emerging areas of inquiry.

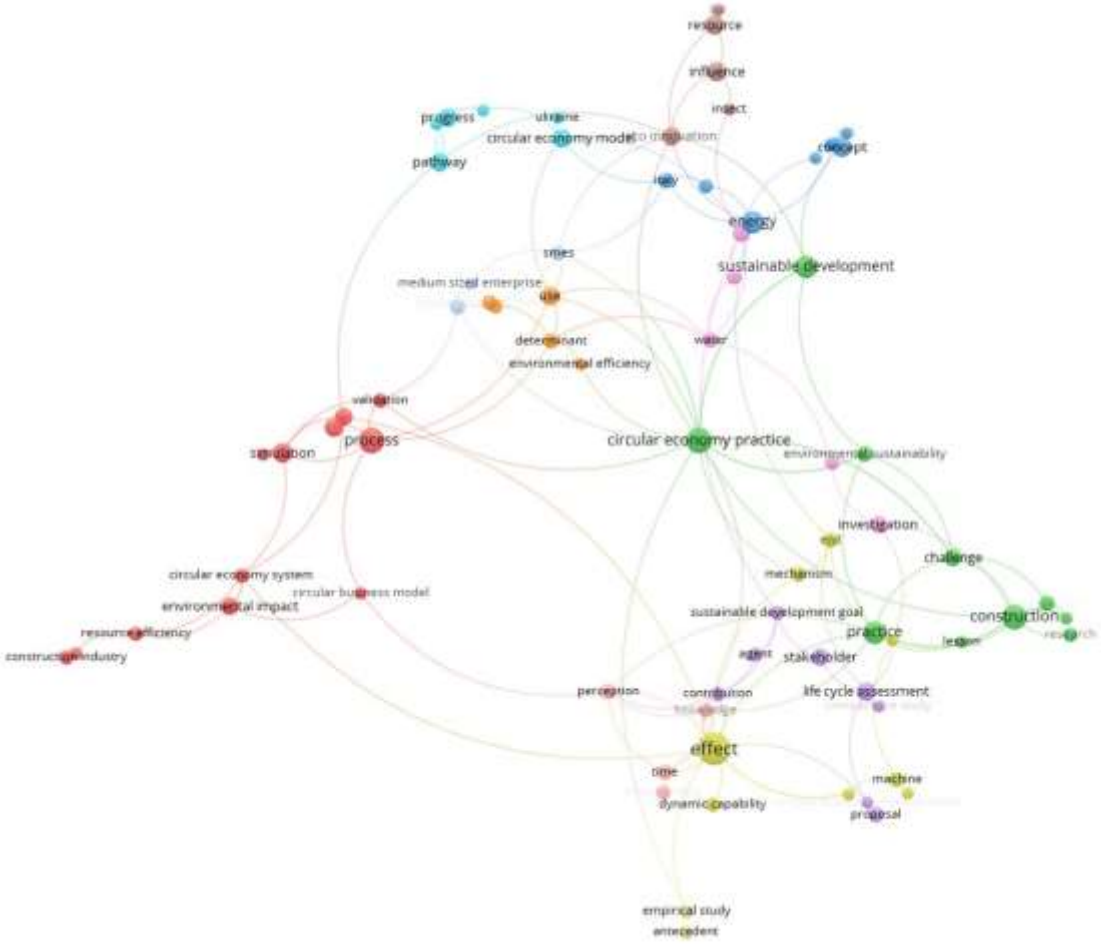

Figure 7. Results map of bibliographic analysis of models and methods for measuring circular economy

The resulting visualization in Figure 7 consists of bubbles grouped into individual clusters, each distinguished by a specific color. The distance and size of the bubbles serve as key parameters for identifying the relationships and frequency of occurrence among thematic areas. Based on the analysis, keywords were categorized into clusters according to the applied color scale. The names of the individual clusters were assigned based on the characteristics of the keywords contained within them. An overview of all clusters is provided in Tab. 4.

Table 4. Results of bibliographic analysis of models and methods for measuring circular economy - clusters

Cluster	Color	Word count	Share of keywords	Identification
Cluster 1	Red	12	15.7 %	Process
Cluster 2	Green	10	13.1 %	Circular economy practice
Cluster 3	Blue	10	13.1 %	Effect
Cluster 4	Yellow	8	10.5 %	Energy
Cluster 5	Violet	8	10.5 %	Synthesis
Cluster 6	Indigo	6	7.8 %	Life cycle assessment
Cluster 7	Orange	5	6.5 %	Determinant
Cluster 8	Brown	5	6.5 %	Eco Innovation
Cluster 9	Pink	4	5.2 %	Food
Cluster 10	Beige	3	4.2 %	Time
Cluster 11	Grey	3	4.2 %	Medium sized enterprises

5. Discussion and Conclusion

The topic of the circular economy is currently the focus of intensive research, which has led to a surge in publications addressing various aspects of the concept, such as recycling, resource reuse, waste reduction, and sustainable production. This interest reflects a global need to transition toward more sustainable economic models, positioning the circular economy as a key subject in both environmental and economic research. While the relevance of this topic is undeniable, general discourse around the circular economy is, in many respects, becoming saturated and fragmented due to the vast number of existing studies. However, when the scope is narrowed to focus specifically on tools for measuring and evaluating the effectiveness of circular economy practices, the research landscape shifts significantly. In this area, the number of studies remains relatively low, indicating a substantial research gap. Measuring and assessing circular processes through indicators, impact assessment tools, or models that quantify the circularity of products and services is essential for understanding the practical effectiveness of circular approaches.

Although such assessment tools are critical for determining the real benefits and performance of circular strategies, this subfield remains underexplored compared to more general topics. This more targeted focus thus represents a promising direction for future research, offering not only opportunities for in-depth analysis but also the development of new methods and approaches for evaluating circularity. Scientific and technical tools for measuring circularity are crucial for informed decision-making in both corporate and governmental contexts. Given the current lack of comprehensive or universally applicable metrics, research in this area could significantly enhance evaluation methodologies and deepen our understanding of the environmental, social, and economic impacts of circular models. Moreover, one emerging area with considerable potential for bibliometric and thematic analysis is the intersection of the circular economy and artificial intelligence. Although this intersection has begun to receive increasing attention, notable research gaps remain, particularly concerning the ethical implications of AI applications in circular manufacturing, including data privacy and labor market disruption. Likewise, the long-term economic and social sustainability of AI-driven systems in low-income and developing countries has yet to be thoroughly investigated. These limitations emphasize the importance of expanding future research to address not only technological solutions themselves but also their broader systemic and ethical implications.

This study offers a comprehensive bibliometric analysis of the current scientific landscape surrounding the circular economy, with a particular emphasis on models and methodologies for its measurement. Based on the review of 701 peer-reviewed articles from the Web of Science and Scopus databases, the analysis identified key thematic clusters, leading authors, geographical trends, and under-researched areas. The findings demonstrate a growing academic interest in circular economy topics, particularly after 2015, driven by global sustainability goals and policy initiatives.

At the same time, the analysis reveals a critical gap in the development and standardization of circularity assessment tools. While general areas such as waste management, recycling, and resource efficiency are well-represented, there is a lack of consistent and universally accepted metrics that would enable systematic assessment across sectors and regions. This absence of unified evaluation frameworks hampers the ability of policymakers, businesses, and researchers to monitor progress effectively and implement evidence-based strategies.

Future research should therefore prioritize the development of standardized indicators, models, and impact assessment tools capable of capturing the complexity of circular systems. Addressing this challenge will require interdisciplinary collaboration, as the circular economy intersects with fields such as environmental science, economics, engineering, and public policy. In conclusion, while the concept of the circular economy is now well-established within academic discourse, its practical

implementation continues to require further methodological advancement. This study contributes to a clearer understanding of the current state of research and provides a foundation for future studies aimed at bridging the gap between theory and measurable, actionable practice.

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