

Sustainable public policy instruments: revealing global interest in circular economy and eco-innovations

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Abstract: The concept of eco-innovation has become increasingly popular as the industrial industry should move toward sustainability. For businesses to establish core competences in the circular economy model, eco-innovation strategies are crucial components. Academicians are now studying the information behind these corporate decisions, with a growing body of work on the topic. The main goal of the study is to reveal and describe the development and interest in the topic of ecological and environmental innovations through bibliometric analysis. The bibliometric analysis is used to reveal the prevailing trends in the fields of sustainability, sustainable development, green economy, and eco-innovations. The fundamental techniques of comparison, induction, synthesis, analysis, and deduction are applied. In addition, the authors focused on bibliometric analysis, as it allows the processing of huge amounts of data and the creation of scientific maps.

The development process in various countries around the world is diverse. Environmental and ecological innovations appear to present a substantial challenge. The prioritisation of the circular economy is also observable in scientific publications and in the academic sphere. Bibliometric analysis reveals the increasing popularity of the circular economy and eco-innovations among authors, indicating the unavoidable need to tackle a more sustainable approach to economic and production activities.

Keywords: circular economy, eco-innovations, sustainable public policies, sustainable development.

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Introduction

Over the past few decades, the rapid advancement of environmental pollution, resource scarcity, and irreversible climate change have become serious concerns for civilisation. Businesses are mostly blamed for the current status of the environment, particularly those in the pollution-intensive industries. Nonetheless, businesses are being forced to be inventive in their business operations in order to achieve both environmental and economic goals, thanks to market incentives and government pressure (Djibo et al., 2022). Sustainable development is currently one of the primary goals that producers, intermediaries, and distributors work toward along the value chain. (Dabija et al., 2020). Public sector initiatives are essential because they have the potential to enhance and develop the sustainability of individual enterprises and, as a result, countries. In this context, the industrial sector, which is considered the main source of pollution, demonstrates a unique requirement. Individual countries are increasingly addressing the practical implementation of the circular economy in their public policies, primarily through radical but also incremental eco-innovations, in an effort to closer align with the objectives of sustainable development. This study serves as evidence that environmental protection and consequent sustainable production and consumption are of paramount importance.

Environmental innovation is sometimes substituted with other terminology, such as ecological innovation, sustainable innovation, or ecological innovation. The concept's participation in this area of management or economics is primarily what makes it regarded as multidisciplinary (He et al., 2018; Bossle et al., 2016). Because of the way the world is going these days, there is much discussion about the sustainable development of EU regions (Vatamanescu et al., 2019). Economies are driven to embrace ecological practices that can aid in resource conservation and boost productivity in creating green ecosystems as part of the quest for green development. Gaining access to innovative resources and improving skills through ecological integration are the keys to achieving innovative performance and creating a long-lasting competitive advantage (Loucanova et al., 2022).

A recent trend in the professional literature on entrepreneurship has been to examine company strategies that prioritise sustainability in terms of the environment while also considering its social and economic aspects (Mikusova, 2017). Another issue that has to be addressed now is how to ensure that enterprises can survive into the future. The goal of the European Union is to gather transparent, reliable, and comparable data about the current state of the environmental impacts of manufacturing and non-manufacturing enterprises, as well as the subsequent adoption of green technologies and innovations that will enable these businesses to grow sustainably in the future. A corporation needs to meet several requirements in order to go green. For instance, they could involve managing or governing the full value chain of a certain service to reduce its effects on the external environment, substituting raw materials, altering production procedures, or introducing new products through various technologies—eco-innovation (Domaracka et al., 2023;

Koirala, 2019). These business models' foundations include innovation, environmental responsibility, and long-term sustainability. In the fields of information science, management, sustainability, and innovation studies, digital transformation has grown in importance (Kochetkov, 2023). With the use of digital and information communications technologies (ICTs), it transforms the ways industries and organizations create value (Vial, 2019). Within the industry, digital technologies drive digital revolutions and power Industry 4.0, the fourth industrial revolution. Through digitisation, digitalization, and digital transformation, digital technologies propel business model developments for companies (Nagy & Lazariou, 2022).

Understanding and analysing the ways in which the literature on eco-innovation has been framed is essential. In view of the mentioned facts, the following research questions were defined:

RQ1: Which publication categories predominate in the Web of Science database?

RQ2: Which countries, associations, and on what time horizon are they most interested in the topic of circular economy and eco-innovations?

The paper is divided as follows: The literature review section presents the importance of the eco-innovations in the context and emphasises the significance of bibliometric analysis in this area, the circular economy concept. The methods used for document selection and search, as well as the instruments utilised for quantitative analysis, are described in the methodology section. The results section describes the main findings made through the bibliometric analysis. This part focuses on the analysis of the established research questions. The discussion section emphasises similar research that has been done in this area. In order to identify similarities and variations across the conducted investigations, the results are also compared in this part with those from other studies. Important findings are mentioned in the conclusion section, along with impending difficulties and limitations that affect the research.

1. Literature review

Small and medium-sized enterprises (SMEs) play a crucial role in the economies of all nations worldwide (Belas, 2023). Management can ensure that corporate financial performance continues to progress by concentrating on a retrospective analysis of the financial situation, which can help them learn from past mistakes (Gajdosikova et al., 2024a). Corporate ethics, corporate governance, and corporate social responsibility are the three fundamental pillars that are primarily designed to advance business transparency (Prochazkova and Micak, 2023). The authors refer to the triple bottom line as three primary areas within CSR: the economic area ("profit"), the social area ("people"), and the environmental area ("planet"). CSR refers to the responsibility of companies and business entities for their impact on society and the environment (Betakova et al., 2023; Zvarikova et al., 2024; Nagy et al., 2022). Enterprises operating in rapidly changing market sectors strive to respond to

competition or established client demands by adjusting to new forces and environmental influences (Gajdosikova et al., 2024b). The impact of corporate social responsibility (CSR) policies on reputation and, consequently, on business performance has made them increasingly important in corporate plans. Effective communication of corporate social responsibility (CSR) initiatives is crucial and must be handled in engagements with stakeholders (Crişan-Mitra et al., 2020). Increasingly, the necessity for a comprehensive strategy that takes into account social, ecological, and economic contexts has triggered a fundamental change in the corporate sphere.

Customer service and process automation are becoming increasingly demanding in the business sector, and there are numerous development opportunities associated with them (Mariciuc, 2023). An alternative to the linear model is a closed-loop system, which guarantees a continuous flow of materials. This framework introduces the concept of a circular economy, connecting the disposal of refuse and resource utilisation to transform the linear system into a circular one. Institutional, social, organisational, and technological factors influence eco-innovation (EI). Carrillo-Hermosilla and colleagues. Pan et al. (2015) said that EI is innovations that show how environmental concerns are integrated into the innovation process. These innovations require businesses to make changes to their organisational and technical structures in order to lessen their environmental impacts. These changes are driven by things such as environmental regulations and competition.

The concept was also of interest to politicians who influenced local, regional, national, and international administrations, as well as intergovernmental organisations. Globalisation, excessive consumption, industrialisation, mass production, and consumer society have all had significant negative effects on the environment. The global and ecological disaster stems directly from the pursuit of social progress and ever-increasing profit, as demonstrated by the growing waste of energy and resources and the accumulation of large amounts of waste. Milanovic and Eric (2024) state that there are several methods to observe the impact, such as the continuous loss of natural capital as a result of waste, the contamination of natural capital by trash, and the general deterioration of the ecosystem. More precisely, the linear economy can be illustrated by the transformation of natural resources into garbage. The circular economy aims to achieve equilibrium between environmental preservation, resource sustainability, and economic development (Lazaroiu et al., 2020).

The circular economy model, which provides a workable transition from a linear to a sustainable economic model, is one of the main tactics for creating a sustainable future. The circular economy model aims to promote production and consumption with as minimal loss in renewable energy, materials, and other inputs as feasible in order to accomplish product reuse. Reuse is made easier by successful recovery, product and service recovery, recycling, consumption with minimal material and energy losses, and recycling (Kirchherr et al., 2017; Elia et al., 2017). Researchers and practitioners are delving more and deeper into the circular economy paradigm (Schroeder et al., 2019). Among the traits of the circular economy are

regenerativeness, intensification of natural capital, optimisation of stocks and resource production, and potential for innovation, job creation, and economic growth (Drejerska et al., 2020). When establishing sustainable directives, the European Union serves as a model. For example, Poland has regulations to adopt a circular economy, although it faces a lack of organisational and financial solutions. The Netherlands, for example, has promoted subsidies for product design and innovation; Belgium has adopted subsidies to encourage packaging recycling. Austria has used subsidies to reduce pollution and waste.

The circular economy emerged as a theoretical framework in the early 21st century. It was a breakthrough in understanding because this model of the economy is also referred to as an agreement on the prioritisation of those parameters of the economic environment that should lead to the efficient use of raw materials and the creation of repeated and new production cycles (Barreiro-Gen & Lozano, 2020). The circular economy represents an approach to industrial ecology, which is taken as a scientific approach dealing with material and energy flow with the aim of creating processes that minimise the negative impact on the environment, including the most important component, which is the minimisation of waste. The concept of a circular economy has garnered significant scholarly interest. The traditional linear economic models are replaced by this relatively new idea. To achieve the highest levels of circular economy, however, is a complex undertaking that requires understanding of certain aspects. This will help ensure a smoother and more effective transition to a circular economy (Skvarciany et al., 2021; Razmiene, 2019). In addition, the organisation configures and coordinates production, logistics, IT, marketing, investment, and customer service departments to close material and energy loops for maximum efficiency and performance. Companies in both developing and developed countries are under pressure due to a growing awareness of the environmental impact of production (Amin et al., 2024). It is obvious that the sustainable behaviour of companies leads to an increase in added value, since in the current environment it is necessary to consider not only profit maximisation as the primary goal but also production that minimises the negative impact on the environment.

The circular economy, as a comprehensive approach and concept, can bring benefits not only to society but also to individual countries and companies that carry out their activities there. This can lead to environmental, economic, and social benefits. These facts lead to the knowledge that the implementation of the circular economy is an attractive option, which, however, is only in the beginning of its development in many countries. However, this model has enormous potential (Bocken et al., 2016; Geissdoerfer et al., 2017).

In a linear economy model, natural resources and any other materials are processed to produce a product that is consumed and discarded if the product's value runs out. These models focus only on the fulfilment of human desires without paying much attention to nature, which gives us many benefits that we can take as the main ingredient for most production activities. Initially, the linear economy was introduced in the industrial revolution and spread throughout the world. However, there are many disadvantages that lead to social, economic, and environmental

problems compared to the advantages that are linear (Neves and Marques, 2022; Upadhayay and Alqassimi, 2018; Heshmati, 2017). The reduction of environmental impact is the main objective of environmental sustainability, which is achieved through the prevention of pollution and the efficient use of natural resources and materials (Odiachi et al., 2023).

2. Research methodology

The fundamental techniques of synthesis, analysis, induction, deduction, and comparison were employed by the writers to accomplish the paper's primary goal. Furthermore, give the bibliometric analysis more attention in order to display the outcomes. Information and communication technologies have sparked interest in bibliometric research because they make it possible to process vast volumes of data and produce complex scientific maps, which are frequently used to display the findings (Durana et al., 2020). Researchers use bibliometric analysis for a variety of reasons, such as identifying new trends. Therefore, properly conducted bibliometric studies can create a solid foundation in various fields (Donthu et al., 2021). A conceptualisation that reveals trends and structural composition in the field of scientific research is the basis of bibliometric analysis. This review is exhaustive in terms of co-authorship patterns, intellectual structure, and various patterns. This approach is particularly well-suited for the analysis of large volumes of data. It is particularly effective in the mapping of the research area and the identification of key publications, authors, and journals that have influenced the debate in general. A bibliometric study involves quantitative content analysis using a variety of metrics, including h-index and citation count (Passas, 2024).

Using all the considered articles that were downloaded from the journals, the VOS viewer was then used to build the term/bibliometric maps based on the co-occurrence frequencies of words, which are a commonly used measure of the relatedness of terms (Van Eck et al., 2010). The concept of VOS ("visualisation of similarities") was introduced less than two decades ago to facilitate the analysis. Subsequently, the VOS concept was transformed into a bibliometric analysis program known as VOSviewer, which is now extensively employed in bibliometric and citation studies to generate and display bibliometric networks that include journals, researchers, or individual publications (Van Eck et al., 2010; Bukar et al., 2023). In the visualisation of a map, items with a higher weight are shown more prominently than items with a lower weight. The links attribute and the overall link strength attribute are the two common weight attributes. The links and total link strength properties for a particular item show how many links it has with other items and how strong those links are overall. The terms in the same cluster have stronger relationships than terms in other clusters. An item can only be a part of one cluster. In the VOS viewer, items can have a variety of properties. Item labels and default circles are used to represent items in the network visualisation. An item's colour is defined by the cluster to which it belongs. Links are shown as lines between things. The stronger the relationship

between the objects, the bolder the line. According to Garcia-Machado (2018), the VOS viewer is a fantastic resource for creating author and journal maps based on co-citation information or keywords. Due to its overall sophistication and user-friendliness, VOSviewer was implemented in this investigation. It is also readily accessible to scientists as open-access software. In fact, a comparative analysis with multidimensional scaling techniques indicates that VOSviewer may have some advantages (Kovac et al., 2024).

The databases utilised for searching and compiling the record bank in this study were Scopus and the Web of Science (WoS). These databases were selected for their compatibility with bibliometric analysis tools, academic emphasis, and their utility in creating search equations. The title, authors, affiliations, keywords, and all citation information for each paper are included in each exported entry. The data were subsequently transferred to the VOSviewer software.

Table 1. Searched keywords in WoS database

Key search terms related to circular economy and environmental pillar of CSR	“circular economy” OR “environmental pillar of corporate social responsibility” OR “environmental pillar of CSR”
Key search terms related to ecological and environmental innovations	“eco-innovation” OR “eco-innovations” OR “ecoinnovation” OR “ecoinnovations” OR “ecological innovation” OR “ecological innovations”

Source: own processing

The database information was compiled using VOSviewer and Bibliometrix, implemented in R version 4.3.3, respectively. The bibliometrix R-package provides a set of tools for quantitative research in bibliometrics and scientometrics. In contrast to the majority of free software (VOSviewer), Bibliometrix prioritises the accuracy and statistical completeness of its findings in addition to data visualisation. For instance, VOSviewer exclusively permits the visualisation of networks, but it does not permit the analysis of the collection in accordance with the various levels of analysis (such as source impact, source dynamics, document analysis, word analysis, and so forth) as outlined in Biblioshiny. Biblioshiny provides an interactive web interface that enables users to conduct pertinent bibliometric and visual analyses (Aria and Cuccurullo, 2017; Dervis, 2019; Giannetti et al., 2023). Over the course of this procedure, redundant documents were eliminated. When documents were found in both Scopus and WoS, the WoS citation was selected.

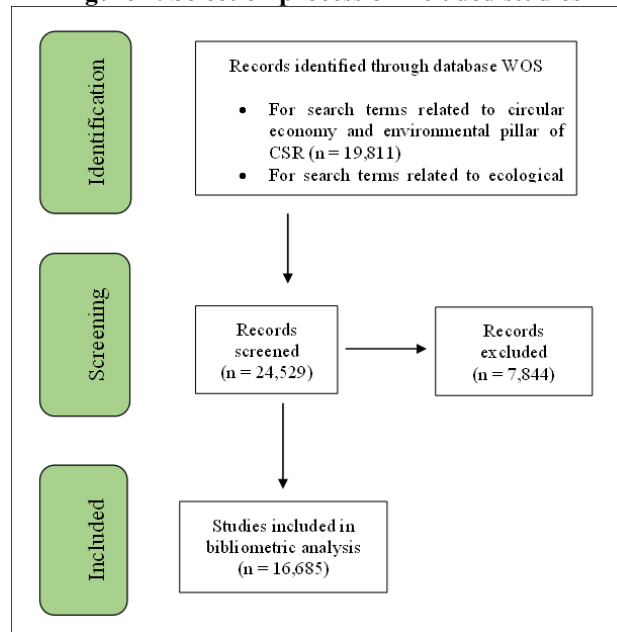
In the database, the study examines the behaviour of trends, concepts, and challenges related to the circular economy and eco-innovation. In this study, the Web of Science (WoS) database was used to search and compile records. Considering the importance of environmental friendliness nowadays, it is crucial to develop knowledge in this area, while at the same time we try to implement more and more efficient processes from an economic and environmental point of view. In this study, the following

criteria were considered for the document sample selection based on the identified knowledge gaps:

- Duplicate documents were deleted.
- The study contains only scientific articles.

For the procedure of selecting individual studies, the authors used the diagram, which serves to clarify the entire process of selecting relevant studies. The whole process is shown in Figure 1. In the database, the authors searched only for research articles because they represent the most comprehensive and relevant source of data. The investigated period of years is set in the time horizon of 2006 to 2024, because it is from year 2006, that it is possible to observe research articles devoted not only to the theorem of the circular economy and eco-innovations, but also to practical use in business practice. A total of 24,529 articles were viewed in the database. Of this total number, 7,844 were excluded as they were not scientific articles.

Figure 1. Selection process of included studies



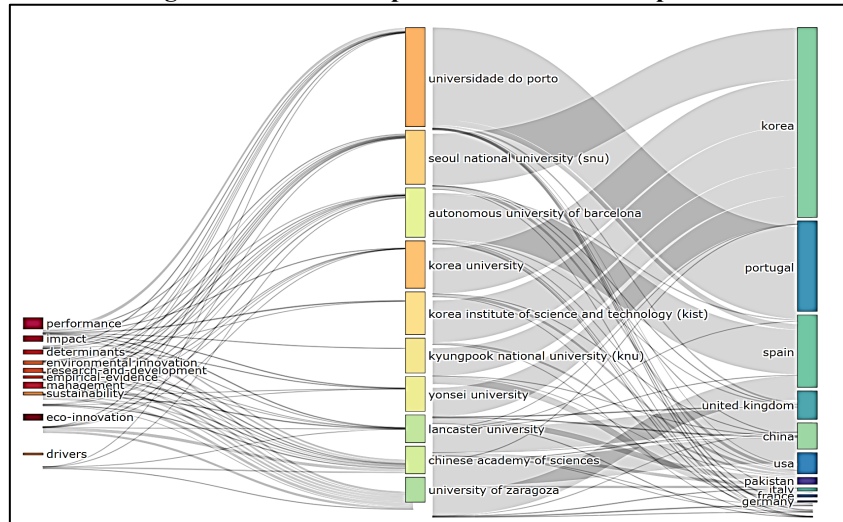
Source: own processing

In total, the authors included 16,685 scientific articles in the bibliometric analysis, which represents a strong basis for further research. The concentration on scientific articles is evident, as these publications are the only sources of pertinent and practical information regarding the subject matter under investigation (Figure 1).

3. Results

The topic of circular economy and eco-innovation is a current topic in various areas and countries. It is for this reason that a bibliometric analysis is performed. In this

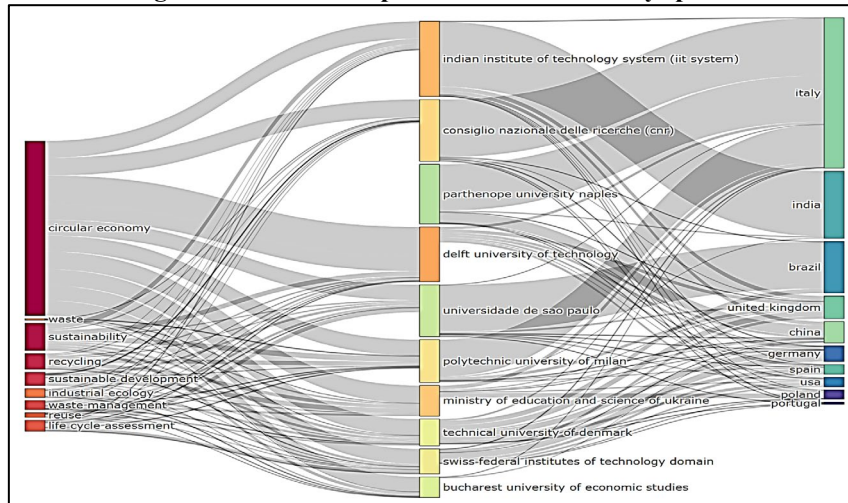
Figure 4. Three-Field plot in eco-innovation sphere



Source: own processing in Biblioshiny

Analysing the concept of circular economy requires a similar approach to that of eco-innovations. Again, the authors performed this analysis using Biblioshiny, with a three-field plot rendering. This analysis reveals a significant number of keywords, with the concept of the circular economy dominating the most. This fact is also supported by the column's width for this term. Terms such as waste, sustainability, sustainable development, and others are directly related to the circular economy. Affiliates from Italy, India, Brazil, the United Kingdom, and China have a strong presence in this area (Figure 5).

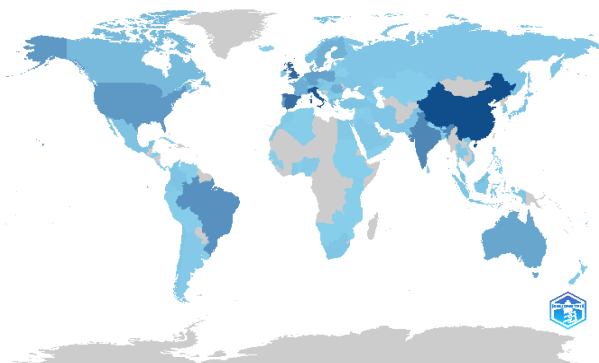
Figure 5. Three-Field plot in circular economy sphere



Source: own processing in Biblioshiny

For illustrative purposes, the authors also rendered the world map according to the number of scientific publications. Based on Figure 6 it is clear, by the darkest blue colour, that China dominates the publications. Among the European countries, Italy, the United Kingdom, Portugal, and Spain are the most concerned with publications on the circular economy and eco-innovations.

**Figure 6. The world map of scientific publications
in the field of circular economy and eco-innovations**



Source: own processing in Biblioshiny

The demonstrable impact of the circular economy is undeniable. The practical introduction of the principles of sustainable development and the circular economy system is crucial not only for companies but also for individual countries, because based on the positive effects of the introduction of this system, countries can not only compare the achieved results, but above all introduce the same or similar activities aimed at reducing material use, redesigns materials and products to be less resource intensive, and many others.

4. Discussions

The global demand for green innovation management is increasing, prompting businesses to continue implementing green innovation strategies and managing their green potential in order to enhance organisational performance and safeguard the environment (Wasiq et al., 2023). The concept of sustainable company performance has garnered significant attention in the highly competitive business environment. Industries have significantly increased their adoption and implementation of circular economy strategies. A business may accelerate the attainment of sustainable corporate performance by implementing a well-established circular economy strategy. Businesses that implement eco-innovation are more adept at capitalising on emerging development opportunities and achieving a higher level of consumer satisfaction. Consequently, eco-innovation is a powerful instrument for environmental protection that also benefits society and the economy (Domaracka et

al., 2023). Research generally indicates that engaging in partnerships with external entities can result in internal efficiency and resource optimisation, ultimately reducing expenses and enhancing the competitive advantage of the organisation (Klewitz et al., 2012). Multiple authors in recent years have demonstrated that green collaboration exerts a substantial effect on eco-innovation (Aboelmaged and Hashem, 2019) and offers favourable outcomes on green patenting activities, as well as the overall innovative capability of the companies (Moro et al., 2019).

Business administration and management, green technology, eco-design, circular economy, environmental effect, and product performance seem to be the strongest trends according to the results. Among the most significant results are those related to economic aspects and cost compensation, which help to enable the shift toward environmentally friendly industry innovation? One useful concept for inspiring environmental solutions is the circular economy (Paipa-Sanabria et al., 2024). According to the study Sumakaris et al. (2020), and in light of the dynamics in economic, ecological, and social contexts, we contend that there exists a strong correlation between eco-innovations and internationalisation. In addition, there is a continuous growth in research trends exploring the interrelationships between these two study areas. This is substantiated by the fact that scientific papers on chosen subjects see exponential increases annually. Nevertheless, the industrialised countries, namely the USA and the United Kingdom, exert the greatest influence on research into these subjects. Evidently, these countries are implementing the most substantial measures at both the political and corporate levels to promote sustainable development. Nevertheless, the next analysis must also consider developing nations. In recent years, there has been an increase in the interest in sustainability and eco-innovation strategies among academics, governments, and corporations, according to the study conducted by. However, the study by Lopez-Perez et al. (2024) demonstrates that despite the fact that researchers have not yet reached a consensus regarding the impact of eco-innovation strategies on business performance, most of them believe that the profitability of these companies will be positively impacted, either in the short or long term. Conversely, some authors believe that the impact will not be positive for their profitability but will be positive for their market value (Hojnik et al., 2018; Liao, 2018). A circular economy can be a valuable instrument for cooperatives to achieve the fundamental pillars of sustainability, as is already apparent. Particularly in economically marginalised regions, cooperatives are instrumental in the implementation of the circular economy by viewing it as a catalyst for sustainable development. Some solutions for environmental sustainability and decarbonisation are already in existence; however, they frequently encounter constraints and substantial expenses (Guerreschi and Diaz Lopez, 2023). In summary, the interconnection between digital transformation and eco-innovations offers opportunities for businesses, governments, and society as a whole. This is due to the fact that the adoption of digital technologies can facilitate the development and deployment of eco-innovations, which can subsequently enhance environmental sustainability and promote economic growth. Additionally, the success of this integration is contingent on the establishment of effective policies, collaborations,

and innovations that strike a balance between economic growth and environmental sustainability. A collaborative effort from all stakeholders, including businesses, governments, and individuals, is necessary to facilitate the transition to a more sustainable and digital economy. It is essential to continue researching and developing sustainable and innovative solutions that capitalise on the potential of both eco-innovations and digital technologies as we progress toward a more interconnected world (Dionisio & Paula, 2024).

The potential for advances in various areas, including resource optimisation, smart decision making, predictive modelling, and innovation and design, is significant due to the interconnectedness between AI (artificial intelligence) and eco-innovations (Piccarozzi et al., 2022).

5. Conclusions

The world's countries are developing in different ways. These countries' economies should reflect their activities in relation to many external factors. Through application of different methods and software — graphs, bibliometric maps in VOSviewer, and figures and maps in Biblioshiny — this study arrived at its findings. Based on these findings, it is possible to declare that the set objective of the study has been met. Bibliometric analysis revealed the fact that the topic of circular economy and eco-innovations is increasingly popular among authors, which is related to the inevitable need to solve a more sustainable way of economic and production activities. Above all, interest in the topic of the circular economy is constantly growing, and it is possible to assume that this trend will continue in the coming years. In connection with the key terms, terms such as eco-innovation, circular economy, performance, sustainability, sustainable development, and others, which are directly related to the concept of the circular economy, were the most frequent. It remains an intriguing finding that, in addition to Korea, China, selected European countries (such as Italy or the UK) also deal with the topic the most. This finding is a positive signal that can help other European countries become more aware of the topic of circularity. This fact is also confirmed by the compiled three-field plot, which ranked Italian affiliations as those that are most active in the European area on the topic of circularity. The graphically compiled world map also confirms this fact.

Future research can address several limitations of this study. Although the scientific database Web of Science includes a substantial part of the world and relevant scientific articles, there are also other scientific databases (such as Scopus) that could expand this research and provide even more relevant results. One limitation of bibliometric analysis is its primary focus on quantitative metrics, such as the number of publications and their development.

The study's findings may be beneficial to the management of the countries in determining the most effective approach to restructure their operations and reevaluate their strategy. Undoubtedly, one of the potential research directions in the

field of eco-innovation is the enhancement of collaboration among institutions (businesses, industry, and research units). The authors of the study may incorporate measures from other innovation reports in future research to more accurately characterise the differences among individual categories of countries. Undoubtedly, one of the potential research directions in the field of eco-innovation is to improve collaboration among institutions. In future research, the authors of the study may incorporate measures from other innovation reports to more accurately characterise the differences among individual categories of countries. Such indexes can include, for example, the Eco-innovation Index, the Global Innovation Index, or the European Innovation Scoreboard, which also examines partial indicators of environmental sustainability. These findings could help to understand regional differences and to better understand the differences in barriers that are found in the implementation of eco-innovations and circular economies.

Conflict of Interest Statement

The authors declare that the research was conducted without any commercial or financial relationships that could be construed as a potential conflict of interest.

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