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Review

Exploring the Landscape of Eco-Innovation: A Bibliometric Analysis of Concepts and Trends in the Manufacturing and Shipbuilding Industries

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Abstract: Eco-innovation (EI) as a conceptual approach has gained significant momentum in the transition of the manufacturing sector towards sustainability. This paper aims to contribute to the study of the research landscape on EI in the manufacturing industry by applying a bibliometric methodology and identifying prevailing trends and concepts used in academic literature. For this purpose, search engines such as Scopus and Web of Science (WoS) were utilized, along with analytical tools such as Bibliometrix, Microsoft Excel, and Gephi. The search was conducted using equations constructed from keywords deemed relevant to the objective, and the records obtained from the databases were consolidated into a single repository for joint analysis using the RStudio platform. The findings revealed an increase in scientific production from 2010 onwards. The analysis identified that the most influential authors, affiliations, and documents primarily originate from Spain, Germany, and China. The key concepts identified are the circular economy, eco-design, and green technologies, which provide a holistic framework for improving efficiency, reducing waste, and mitigating environmental impacts. EI promotes close collaboration between industries to reduce the ecological footprint. Nonetheless, there is a notable gap in research about EI in the shipbuilding industry, necessitating further exploration in the sector. This study lays a foundation for future investigations in this evolving domain.

Keywords: eco-innovation; bibliometric analysis; green technologies; green products; shipbuilding industry; naval sector; manufacturing industry

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1. Introduction

The rapid technological progress witnessed in the world has enabled the facilitation of various aspects related to the quality of life of individuals, creating value through the application of knowledge generated across multiple disciplines. The OPSI [1] notes that this knowledge transfer to society is reflected in different dimensions of human well-being, such as improving the coverage and quality of public services, the efficiency and transparency of organizational and business management, and the increase in citizen participation, among others. However, over the years, the indiscriminate exploitation of resources for the transformation and production of artifacts did not consider the environmental implications and the impacts on the sustainability of future human activities.

The environmental problems generated by human activity affect human well-being, as evidenced by soil degradation, which compromises future food security [2], or the records of premature deaths due to air pollution [3]. According to Hoesung Lee [4], the efforts to

curb climate change are of interest because, in addition to reducing environmental impacts, they reflect on the sustainability and well-being of the environment, generating a positive impact on the economy.

In a world aware of such consequences and that advances exponentially every day, it has become necessary to consider and implement eco-friendliness as a fundamental factor in developing products, processes, structures, and policies in pursuit of the sustainability of societies, human activity, and well-being. Accordingly, the United Nations has developed strategies to migrate towards the sustainability of current and future civilizations, such as the 2030 Agenda and the Sustainable Development Goals (SDGs). Stafford-Smith et al. [5] affirmed that the SDGs provide an integrative and holistic framework to address sustainable development challenges. However, their implementation requires significant coordinated efforts from the local level of civil communities to the global level of countries and companies, where the commitment falls on multiple agents acting in isolation, jointly, or globally.

For this reason, today, there is a focus on ensuring that the manufactured artifacts are efficiently integrated into the planet's natural cycles. In this sense, innovation has become a fundamental tool for the progress of different industries, especially manufacturing. According to Porter [6], innovation in the manufacturing industry is crucial to maintaining competitiveness in a demanding environment, so companies seek new technologies and methods to improve dimensions such as quality, efficiency, and responsiveness.

In the current paradigm, incorporating environmentally responsible technologies is a mandatory step in the face of a world with high ecological demands. Schumacher [7] introduces the term "intermediate technologies" or "appropriate technologies" to refer to those technologies through which the objectives are achieved with minimal consumption of resources, thus reducing production costs and environmental impacts. However, the first appearance of the term EI dates back to 1972, when significant concerns about the environmental impacts of human activity and the need to address them through the creation and transfer of technology began to emerge [8].

The term EI has gained greater attention and recognition in the present day. This concept has been consolidated as a key approach to promoting sustainability and efficiency in production processes, stimulating the creation of products and services that minimize their environmental impact and promote sustainable development. Fussler and James [9] define EI as any innovation that reduces negative environmental impacts, regardless of the intention.

A clear example of the application of the EI concept can be found in the efforts developed by nations to integrate environmental dynamics with improving the well-being of civil societies, as in the case of the creation of fluvial and maritime vehicles in the naval sector. Transport activity and its infrastructure enables the development of multiple economic activities. However, it is necessary to consider the ecological environment for the development of suitable means that improve logistical activity. In the intervention of ecosystems through artifacts that allow achieving this objective, developing eco-innovations that integrate social dynamics with natural cycles, reducing the conflict that may arise between these two dimensions of performance and well-being, is necessary [10].

The naval industry plays a significant role in the global maritime transportation of people and goods. Compared to other manufacturing sectors, the naval sector demands a wide range of services, from design to the construction, repair, and maintenance of vessels and artifacts for both riverine and maritime navigation. Additionally, it requires specialized materials, machinery, and equipment to carry out these processes and manufacture components that meet its requirements. The application of eco-innovation in the naval manufacturing industry (shipbuilding industry) aims primarily at developing more efficient vessels in terms of energy, emissions, and material usage. This is achieved through the incorporation of dynamic practices of recycling, reusing, and reducing environmental impacts.

Given this context, it is necessary to analyze and comprehend how the literature has been constructed around eco-innovation in the manufacturing industry. To this end, this document aims to address the following research questions.

RQ1: What types of publications are predominant in the selected databases?

RQ2: How has the academic production of eco-innovation in manufacturing evolved annually?

RQ3: Who are the most productive and influential authors, publication outlets, institutions, and countries in eco-innovation research in manufacturing?

RQ4: What are the main research approaches and trends in eco-innovation in manufacturing?

RQ5: Which publications from the selected databases are most relevant to eco-innovation in manufacturing?

RQ6: In what research areas has work been carried out in the shipbuilding industry?

Responding to these research questions involves analyzing the key concepts, trends, relevant areas of study, and other patterns identified in the academic discussion. This analysis allows the generation of a construct that serves as a basis to identify the current state of the literature and its evolution in the research of the manufacturing and shipbuilding industries, recognizing knowledge gaps to propose future research directions.

The paper is structured as follows: Section 2 provides a literature review of the background to contextualize eco-innovation and highlight the importance of developing bibliometrics in this field. Section 3 details the methodology used for document searching and selection and the tools employed for quantitative analysis. Sections 4 and 5 present the results and discussion, outlining the review's findings concerning the records comprising the selected document bank and contrasting them with previous approaches presented in Section 2. Finally, the article concludes with Sections 6–8, addressing suggested future research, study limitations, and conclusions.

2. Literature Review and Previous Bibliometric Studies

A search was conducted to achieve an initial understanding of the EI concept, focusing on previous literature reviews through in-depth document review studies or bibliometric analyses.

2.1. Bibliometric Reviews

In approaches using bibliometric techniques, analysis approaches were found that related EI to green innovation, resource-based views, green products, eco-design, financial performance, circular economy, sustainable development goals, and lean and clean production.

The most significant focus of the EI concept lies in the improvements associated with products and processes. Taddeo et al. [11] reviewed the literature on lean and clean production, concluding that these operational approaches are a type of EI concerning manufacturing activities. Khanra et al. [12] reached a similar conclusion, stating that EI is closely linked to organizational operational activities as a strategy for greening business models by modifying products and processes. Similarly, the exploration conducted by Vaz et al. [13] suggests that eco-innovations are either incremental to adapt existing operations or radical to achieve the greening goal through a paradigm shift in knowledge forms. Finally, Qing et al. [14] and Lopez-Perez et al. [15] found a positive relationship between EI and financial performance, but it is noteworthy that there were social and economic impacts associated with technical change, distinguishing the emergence of emerging economies in response to technology acquired through EI.

This last finding is important because, similar to the broader scope of innovation, technical and organizational change impacts multiple levels of social and cultural networks. Bhardwaj et al. [16] explored the relationship between green innovation and marketing strategies, examining themes such as the relationship between youth and green consumption, "greenwashing", and customer loyalty, where the development of eco-innovations plays an important role in gaining market share and reaching new target audiences. Mart-

inho and Mourao [17] delved into the concept of circular economy, recognizing the role of EI in achieving sustainable economic development and suggesting exploring the concept in business linkage networks and transition measurement mechanisms. Chaparro-Banegas et al. [18], Guerreschi and Lopez [19], Sumakaris et al. [20], and Sanni and Verdolini [21] studied EI relating to regional and national innovation systems, open eco-innovation, and eco-innovation in cooperative enterprises. These bibliometric explorations of EI examined the benefits in the regional economy, changes in policies to develop models of social and economic transition, the mode of technological acquisition and knowledge by small- and medium-sized enterprises (SMEs) in open innovation processes, the existing relationship between social reasons and organizational visions for the adoption of EI, and the interaction among economic actors that allows the creation and development of EI. Finally, the study conducted by Fatman and Haleem [22] demonstrated that the advantage of implementing eco-innovations at the organizational level is not only evident in financial and recursive performance, but also closely related to achieving sustainable development goals and making milestones in political, environmental, and social responsibility issues.

Despite the evident interest in the concept as a current and relevant case for the theoretical development of the innovation phenomenon, EI is highly similar to green, sustainable, and environmental innovation, making it challenging to establish a linguistic identity. This complexity expands and complicates the study of change in favor of environmental impact mitigation [23–25].

2.2. In-Depth Literature Review

Based on an in-depth literature review, the aspects of interest found in the study of the eco-innovation term are detailed in the following sections.

2.2.1. Seminal Authors of Eco-Innovation

Over the years, various authors have addressed the topic of eco-innovation. Among the most prominent is Rennings [26], who proposed the concepts of organizational, social, and institutional eco-innovation to respond to the existing criticism about the instrumentalist perception of environmental sustainability that leaves aside the social dimensions. However, it is necessary to consider that eco-innovation must be worked on comprehensively, and the more global its impact, the better the results will be. Under a market-oriented logic, Pujari [27] defined eco-innovation as all the activities of public or private companies involved in invention, innovation, and technology diffusion. Kemp and Pearson [28] defined eco-innovation as the novelty incorporated into the production, assimilation, or exploitation of a product, the development of a service or management method that, in its life cycle, shows a reduction in environmental impact, pollution, and other negative impacts on resources, compared to other alternatives associated with the improvement of these forms of knowledge. There are two types of innovation: incremental innovation, characterized by a gradual advancement in the forms of knowledge, and disruptive innovation, which implies a radical change in the forms of knowledge [28]. Therefore, eco-innovation encompasses a product and processes in its design, production, operation, and other life cycle stages, studying minor and significant technological changes.

2.2.2. Areas of Eco-Innovation Assessment

Eco-innovation (EI) has institutional, social, organizational, and technological components. Carrillo-Hermosilla et al. [29] defined EI as innovations that reflect the integration of environmental concerns into innovation processes, requiring technical and organizational changes in companies to reduce environmental impacts, using driving tools such as environmental regulation and competitive pressure. Regarding driving tools, we also found documents such as [30], highlighting organizational capabilities and environmental regulations. The documents suggest that current government policies must be adjusted within a regulatory framework to reduce pollution, supported by research platforms to meet this objective.

With clarity on the identified drivers, the concept consolidates more firmly, and efforts to establish parameters for its measurement begin. Kemp and Arundel [31] recognized that using a single methodology is insufficient. Greater emphasis should be placed on the direct measurement of EI results through documentary and digital sources, suggesting the complementarity of the current approach that focuses on innovation inputs (investment in research and development (R&D) or patent registration). The authors suggested direct measurement in products, services, or processes changed through EI, where it is important to evaluate the impact of novelty on expected efficiency, satisfaction, and productivity (the desired change) and emergence (other unintended changes). This is how EI can be measured through indicators such as input measurements, intermediate product measurements, expected product outcome measurements, and indirect impact measurements.

2.2.3. Theories Related to Eco-Innovation

Although eco-innovation may seem intuitive, several theories help establish its foundations and measure its scope. Like any other concept, eco-innovation requires a context to be understood, and its adoption can generate a certain degree of skepticism.

One of the main pillars of the concept is linked to the business context; therefore, some of the earliest theories find their foundation in neoclassical economics. Dryzec [32] related this concept to environmental modernization, stating that academics in this field believe that technology is the answer to environmental problems and support ecological modernization as a profitable avenue for technological development in collaboration with companies and the government. The latter can facilitate environmental considerations through management techniques related to eco-management and cost-benefit analysis, which do not involve high costs and consider the best environmental practices [33].

Multiple theories about the concept's origin introduce organizational innovation linked to the environmental dimension of economic activities and value creation. The Porter hypothesis is an example of this. M. E. Porter and Van Der Linde [34] established that this theory consists of the premise that well-designed, strict environmental regulations can act as a stimulus for innovation within companies, offsetting the cost of implementation through gains in present and future competitiveness. This theory considers the duality between social/environmental performance and the economic return perceived by companies. Knudsen and Madsen [35] supported the Porter hypothesis through the resource-based view. The resource-based view is another relevant theory associated with the study of innovation. In the linkage developed by these authors, it was stated that incompetence in core business activities is reflected in poor environmental performance (pollution is equivalent to inefficiency). However, improving environmental behavior implies an estimate of opportunity costs, where economic considerations and appropriate criteria for environmental behavior must be balanced to achieve the goal of economic and social sustainability of firms in the transition to greening their productive activity.

From institutional and sectoral perspectives, eco-innovation relies on establishing regulations to stimulate change. Hazarika and Zhang [36] argued that institutional theory can explain this need, as the configuration of the institutional framework responsible for regulating market dynamics in a territory can influence the development of organizations. Regarding eco-innovation, the study of institutionality is still in an incipient stage, and private companies are still adapting to the notion of eco-innovation. However, organizations can adopt eco-innovative practices to meet social and governmental expectations around sustainability, thus responding to institutional pressures and government actions.

At the technological level, Sáez-Martínez et al. [37] studied the technological trajectories of small- and medium-sized enterprises, identifying that market-oriented innovation is more successful for the diffusion of eco-innovations. This trajectory seeks innovative solutions that benefit the environment and society in the market dynamics, marking a strategic path that aims to align innovation with sustainability principles and environmental responsibility, considering market demands. Complementarily, the theory of the diffusion of innovation was applied by Kapoor et al. [38] as an evaluation of the factors

influencing the rate of acceptance and success of innovations. This theory establishes that relative advantage, compatibility, complexity, trialability, and observability are the most important attributes that influence adopters' perceptions. In the study of eco-innovation, this theory seeks to evaluate the feasibility and reception of novelties in the market.

When observing the innovation process, routines and similarities can be established in the genesis of changes in artifacts. Under this analytical approach, the TRIZ (Theory for the Resolution of Inventive Problems) and subsequent methodologies have been developed, aiming to recognize how the innovation process works from the identification of the problem to its culmination in the incorporation of the invention into societies, in order to evaluate the impacts of artifacts throughout their life cycle [39]. The relationship between the TRIZ methodology and eco-innovation is evident in the environmental considerations for creating changes in artifacts, whose objective is to minimize the impact on ecosystems with the available technology and knowledge. A clear example of the application of eco-innovation methodology is found in [40], which approached the study of the development of energy-efficient lighting, reflected in the patent of a fluorescent lamp model. Low et al. [41] studied the development of novel and ecological alternatives using TRIZ models, which are based on the analysis of patents and the guidelines identified in the progress of technical systems.

Finally, the study of innovation also implies its perspective from technological diffusion and the associated impacts on various actors in societies. Freeman's stakeholder theory proposes that companies need to understand the relationships they establish with traditional groups such as customers, suppliers, employees, shareholders, institutions, regulatory entities, communities, and other groups of actors to ensure that inventions are efficiently coupled with the dynamics of societies [42]. This theory finds its application to eco-innovation to test that dense networks among the above stakeholders can favor or hinder its introduction [43].

3. Materials and Methods

Bibliometrics will be utilized to address the stated research questions. This approach was selected for its ability to identify emerging trends, relevant research areas over time, and collaborations among authors, institutions, sources of information, or countries. Statistical methods provide a comprehensive understanding of the current state of the literature and documents of interest for consultation regarding a research topic [44–46]. According to Bastos et al. [47], bibliometrics is a research technique that aims to study research trends and identify the state of science on a topic of interest by analyzing metadata contained in the associated records. Figure 1 visually represents the systematic review process used in this research.

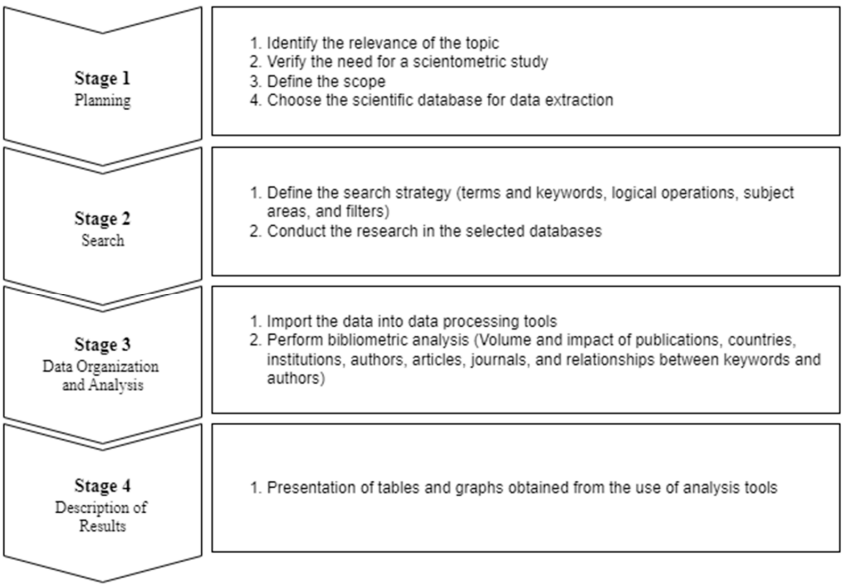


Figure 1. Summary of the systematic process for conducting the bibliometric analysis. Adapted from Bastos et al. [47].

3.1. Planning

The study investigates the behavior of trends, concepts, and challenges surrounding eco-innovation in the manufacturing industry to lay a solid foundation regarding existing materials and potential future lines of research. Developing knowledge in this area is necessary given the importance that eco-friendliness has gained today, seeking to carry out processes that are increasingly efficient, both economically and environmentally [48], where the lens of the study of interest in this research is primarily the manufacturing industry and identifying if exploration has occurred in the specific case of the shipbuilding industry, as investigations of these criteria are still incipient.

Based on the identified knowledge gap, the present research considers the following criteria for selecting the sample of documents:

- The documents reviewed must be of an academic nature;
- Duplicate documents will be removed.

Databases

For this research, the databases used to search and compile the record bank were Scopus and the Web of Science (WoS), chosen for their compatibility with bibliometric analysis tools, academic focus, and the ease of constructing search equations and extracting metadata from documents. These databases were consulted in February 2024.

3.2. Search

In line with the research objective, the keywords utilized for this study were categorized into three groups. The first group comprises the term eco-innovation and its variations, establishing the primary focus of the study. The second group encompasses terms associated with eco-innovation, such as sustainable, green, or environmental innovation. The third group includes terms relevant to the application field of the concept, namely, manufacturing, products, and their performance. The final set of keywords is linked to the shipbuilding industry. These keywords and keyword groups were arranged in this sequence because the investigation aims to exclusively examine the concept of eco-innovation, disregarding its conceptual variations (green innovation, environmental innovation, and sustainable innovation) concerning manufacturing and product design, by the objectives outlined in the introduction. For bibliometric analysis, the equation was defined up to group 3 while addressing question 6, which involved utilizing the group 4 keywords as indicated in the tables. Table 1 illustrates the utilized keyword groups.

Table 1. Keywords.

Group	Keywords
1	Eco-innovation, ecoinnovation, eco innovations
2	Sustainable development, innovation, environmental innovation, energy efficiency, eco-design, environmental technology, green innovation, technology
3	Manufacturing, product design, product, economic development, waste management, green production, environmental impact
4	Naval, boat, ship, vessel, craft, shipbuilding, small boat, shipyard, ships, vessels, sailboat, hull, sail, maritime

In formulating the search equations for the different sets of words, an approach was adopted that involves enclosing each concept within quotation marks. This method facilitates search engines in identifying a concept formed by multiple words as a single term. In this regard, special attention was paid to the search expression of group 2, where each term must be linked to innovation. This relationship was established by using parentheses to define subcategories and using the exclusion connector (AND). The purpose was to find documents that address innovation, the environment, and technology without restricting

the search to identifying compound terms. On the other hand, inclusion connectors (OR) were used to connect all terms that are part of the keyword group. The specific search expressions for each group are detailed in Table 2 of this article.

Table 2. Grouped Search Expressions.

Group	Search Expression
1	"Eco-innovation" OR "ecoinnovation" OR "ecoinnovations"
2	("sustainable development" AND "innovation") OR "environmental innovation" OR ("energy efficiency" AND "innovation") OR (("ecodesign" OR "eco-design") AND "innovation") OR ("environmental technology" AND "innovation") OR "green innovation" OR (("Eco innovation" OR "ecoinnovation") AND "technology")
3	"manufacturing" OR "product design" OR "product" OR "economic development" OR "waste management" OR "green production" OR "environmental impact"
4	"naval" OR "boat" OR "ship" OR "vessel" OR "shipbuilding" OR "small craft" OR "shipyard" OR "ships" OR "vessels" OR "sailboat" OR "hull" OR "sail" OR "maritime"

For the search in academic engines, each search expression per group was written in different rows or search boxes. In Scopus, the category of the boxes was defined as "article titles, abstracts, and keywords", while in WoS, it was defined as "all fields". The intersection connector (AND) connected the three corresponding boxes for each group. Table 3 shows the advanced search equation for each academic engine.

Table 3. Search equations.

Database	Search Equation
Scopus	((TITLE-ABS-KEY ("Eco-innovation" OR "ecoinnovation" OR "ecoinnovations") AND TITLE-ABS-KEY (("sustainable development" AND "innovation") OR "environmental innovation" OR ("energy efficiency" AND "innovation") OR (("ecodesign" OR "eco-design") AND "innovation") OR ("environmental technology" AND "innovation") OR "green innovation" OR (("Eco innovation" OR "ecoinnovation") AND "technology")) AND TITLE-ABS-KEY ("manufacturing" OR "product design" OR "product" OR "economic development" OR "waste management" OR "green production" OR "environmental impact") AND TITLE-ABS-KEY ("naval" OR "boat" OR "ship" OR "vessel" OR "shipbuilding" OR "small craft" OR "shipyard" OR "ships" OR "vessels" OR "sailboat" OR "hull" OR "sail" OR "maritime"))
Web of Science	"Eco-innovation" OR "ecoinovation" OR "ecoinnovations" (All Fields) and ("sustainable development" AND "innovation") OR "environmental innovation" OR ("energy efficiency" AND "innovation") OR (("ecodesign" OR "eco-design") AND "innovation") OR ("environmental technology" AND "innovation") OR "green innovation" OR ("technology") (All Fields) and "manufacturing" OR "product design" OR "product" OR "economic development" OR "waste management" OR "green production" OR "environmental impact" (All Fields) and "naval" OR "boat" OR "ship" OR "vessel" OR "shipbuilding" OR "small craft" OR "shipyard" OR "ships" OR "vessels" OR "sailboat" OR "hull" OR "sail" OR "maritime" (All Fields)

3.3. Data Organization and Analysis

The database information was consolidated using Microsoft Excel and Bibliometrix, executed in R version 4.3.3. During this process, duplicate documents were removed. In cases where documents were present in both Scopus and the WoS, the WoS citation was chosen. This is because the duplicate removal method configuration in R Studio prioritizes documents from WoS.

In an initial analysis, information related to the frequency of publication by year, authors, countries, and institutions with the most publications, the highest impact information sources, the classification of documents by number of citations, and other statistics that allow us to identify the sources of knowledge was extracted.

The tools Gephi and Bibliometrix were used for a more in-depth analysis. The aim was to understand the co-authorship and co-citation networks between authors, the science tree by identifying seminal documents, and the analysis of the co-occurrence networks of keywords, determining the significant areas of study of the concept and its thematic evolution.

4. Results

According to the methodological tracking, the initial search equation search yielded only four documents related to the study of eco-innovation in the shipbuilding industry. This result is insufficient for an objective and specific bibliometric analysis. For this reason, a search equation comprising the first three groups of keywords covering the manufacturing industry in general was used. Since the shipbuilding industry is part of this sector, the obtained results could include relevant studies for our purpose. The search engines yielded 948 results in WoS and 685 in Scopus. During the consolidation of the analysis repository, duplicate documents were removed from both databases, resulting in a sample size of 1368 records as depicted in Figure 2.

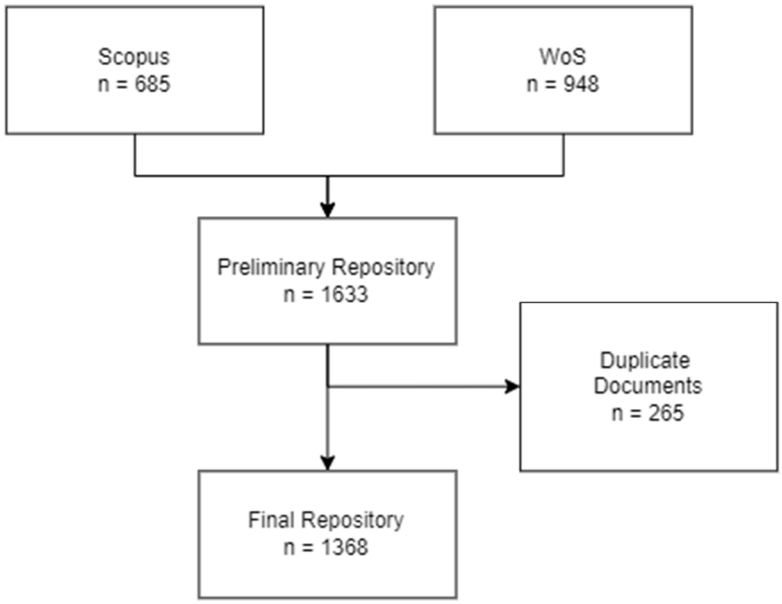


Figure 2. Quantity of records and sample selection.

4.1. What Types of Publications Are Predominant in the Selected Databases?

The joint study of the identified repository found that articles were the most common document type, while book chapters, books, and short surveys were the least frequent, as depicted in Table 4. This suggests that publication in academic journals is the primary channel for disseminating and communicating research in this field. Articles are the preferred and most valued format for presenting and disseminating specialized knowledge.

Table 4. Document typologies. Source: Scopus and WoS.

Rank	Document Type	TP	%
1	Article	1135	82.97%
2	Conference Papers	123	8.99%
3	Reviews	71	5.19%
4	Books	34	2.49%
5	Others	5	0.37%
	Total	1368	100.00%

(TP: Total Publications).

4.2. How Has the Academic Production of Eco-Innovation in Manufacturing Evolved Annually?

The joint study of samples found that the term "eco-innovation" corresponds to a relatively recent concept. As observed in Figure 3, documentation about the concept began to appear around 2000, with a significant increase in production evident in the early 2010s. It was also shown that in the period between 2013 and 2024, academic production was

11.91 times higher compared to the period between 2000 and 2012. The year 2023 showed the highest scientific production regarding the concept, and it is expected to continue increasing in the current and future periods.

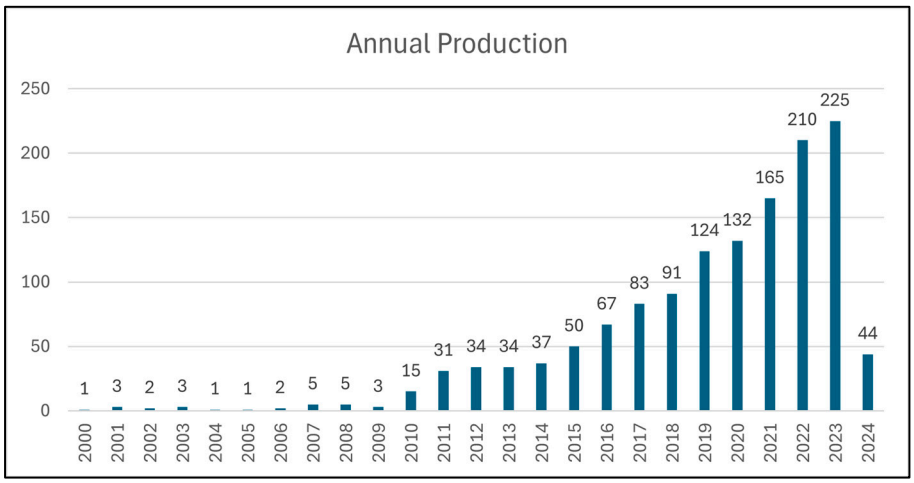


Figure 3. Production over time. Source: Own.

4.3. Who Are the Most Productive and Influential Authors, Publication Outlets, Institutions, and Countries in Eco-Innovation Research in Manufacturing?

According to the results of the search in the selected academic engines, Table 5 presents the classification of countries with the highest number of publications regarding eco-innovation. The top scientific producer was China, which had 1024 publications (74.9%), which may be related to the country's initiatives to promote eco-innovations. Like OECD member countries, China has been using various means to support and promote environmentally related innovation, including public investment in R&D, the mobilization of financing from multiple sources, government procurement of environmentally friendly products, the adoption of regulatory measures and market-based instruments, and awareness campaigns and capacity development, as well as actions at the global level, aiming to boost and facilitate the development of eco-innovations in the country [49].

Table 5. Most influential countries. Document typologies. Source: Scopus and WoS.

Rank	Production		Impact		
	Country	NP	Country	TC	ACD
1	China	1024	China	14,624	43.7
2	Spain	376	Spain	5794	49.1
3	Italy	293	Italy	4229	36.8
4	United Kingdom	176	United Kingdom	2669	56.8
5	France	165	Germany	2605	63.5
6	Brazil	157	Brazil	1867	38.9
7	Portugal	125	Portugal	1774	40.3
8	Malaysia	108	France	1561	29.5
9	South Korea	103	Netherlands	1279	67.3
10	Pakistan	98	Malaysia	1018	26.1

(NP: Number of Publications, TC: Total Citations, ACD: Average Citations per Document).

Several European countries, as depicted in Figure 4, have made significant contributions to EI in the shipbuilding industry. Spain ranks 2nd with 9.7% of total production, Italy with 7.6%, and France with 4.2%. This can be attributed to the regulations adopted by the European Union, which have spurred the development of green innovations and clean technologies. These regulations have made EI an essential driver for achieving a transition

towards sustainability [50]. The impact of these policies is also evident in the scientific production of the American continent, with Brazil ranking sixth with approximately 4.1% of publications, the only Latin American country listed in this top. Portugal follows with 3.2%. The last three countries are of Asian origin, namely, Malaysia, South Korea, and Pakistan, with 2.8%, 2.6%, and 2.5%, respectively.

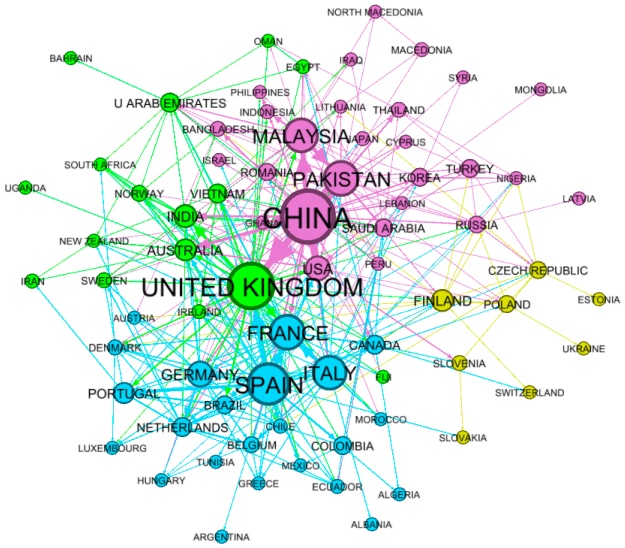


Figure 4. Network of collaboration among countries.

Table 5 lists the countries with the highest number of citations, and there is agreement among the top four countries. However, Germany and the Netherlands were found in the fifth and ninth places, with average citations per document of 63.5 and 67.3, respectively. This result reflects that publications from these two countries have a more significant impact on academic literature.

In the visual representation denoted as Figure 4, the graph illustrating the collaborative relationships between countries in the field of scientific production related to eco-innovation is exhibited. It is observed that this graph reveals the existence of four distinct associations. Two leading conglomerates were distinguished, with one in pink, identified as the Asian cluster, in which collaborations between China, Pakistan, Malaysia, Bangladesh, and Korea can be identified. On the other hand, a blue-toned conglomerate, referred to as the European cluster, is highlighted, where collaborations between the United Kingdom, France, Spain, Italy, Germany, and Portugal can be observed. Within this blue conglomerate, significant collaboration with countries from the American continent is evident, although the production proves to be lower in comparison. Furthermore, independent association conglomerates can be identified, where yellow represents other European countries with lower scientific production, such as Estonia, the Czech Republic, Finland, Poland, and Switzerland. A green-toned cluster is also noteworthy, consisting of countries near the Indian Ocean, such as South Africa, India, Australia, Saudi Arabia, New Zealand, and the United Arab Emirates.

Although collaboration between the European group and countries in the American continent is observed, the scientific production of the latter seems to be lower compared to the Asian and European clusters. Within the conglomerate of European countries, Latin America is represented by Colombia, Mexico, Ecuador, and Brazil. Brazil also stands out as one of the countries with the highest number of documents and citations (6th position in both). This collaboration is not exclusive to this area; according to Belli, S., and Baltà, J. [51], at a general level, the nations that most frequently cooperate in scientific research are the United States, followed by Brazil, Spain, Germany, and France. As collaboration in scientific research between the European Union, Latin America, and the Caribbean

progresses, detaching these networks from the vast global web of scientific cooperation that researchers from all nations are currently weaving will become more complex.

Table 6 presents the top 10 journals with the highest number of publications in the field of study. In the ranking of journals, the total local citations, the journal's impact factor (IF), and its H-index are also relevant. The H-index is an indicator that measures whether an author has as many publications as citations in their publications [52], while the impact factor measures the average number of citations received by a journal in the previous two years [53].

Table 6. Most relevant journals classified by H-index. Source: Bibliometrix.

Rank	Journal	NP	TC	IF	H-Index
1	Journal of Cleaner Production	163	12,422	11.1	60
2	Business Strategy and The Environment	90	4996	13.4	41
3	Sustainability	84	2158	3.9	22
4	Environmental Science and Pollution Research	39	724	5.8	13
5	Technological Forecasting and Social Change	23	1253	12	14
6	Corporate Social Responsibility and Environmental Management	22	882	9.8	13
7	Journal of Environmental Management	17	1247	8.7	13
8	International Journal of Environmental Research and Public Health	16	426	4.614	13
9	Sustainable Development	16	430	12.5	11
10	Sustainable Production and Consumption	14	937	12.1	11

(NP: Number of Publications, TC: Total Citations, IF: Impact Factor).

The vast majority of the journals shown have environmental impact and sustainability as the central area of study in administration; however, within the identified journals, we found areas of knowledge related to economics (Industrial and Corporate Change, Entrepreneurial Business and Economics Review, Economic Research), energy consumption and production (Renewable Energy, Energies, International Journal of Green Energy), or engineering (Technovation, Sustainable Production and Consumption, Kybernetes). In Figure 5, we can observe the proportion of documents by thematic areas.

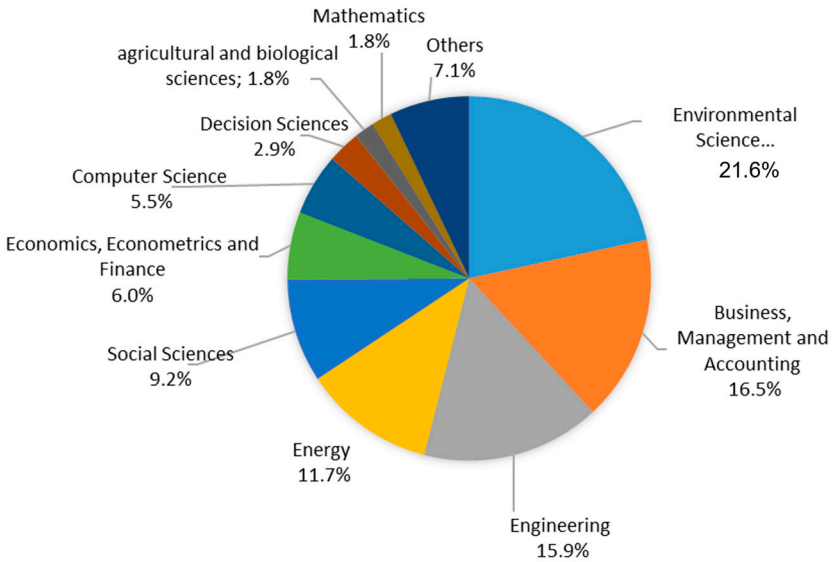


Figure 5. Identified thematic areas. Source: Scopus.

Table 7 presents the classifications of institutions with the highest production of documents related to eco-innovation. Notably, most institutions are observed in China, followed by Spain. Although the University of Porto leads academic production, the University of Zaragoza significantly impacts the research carried out according to the average number of citations per document.

Table 7. Affiliated institutions with higher production.

Rank	Affiliation	Country	NP	TC	ACD
1	University of Porto	Portugal	21	738	35.1
2	Zhejiang Sci-Tech University	China	20	706	35.3
3	Jiangsu University	China	17	345	20.3
4	University of Castilla-La Mancha	Spain	16	938	58.6
5	Northwestern Polytechnical University	China	13	728	56.0
6	Polytechnic University of Valencia	Spain	12	185	15.4
7	Xi'an Jiaotong University	China	11	286	26.0
8	University of Zaragoza	Spain	10	973	97.3
9	Jimei University	China	9	412	45.8
10	University of Naples Parthenope	Italy	8	162	20.5
11	Nanjing University of Aeronautics and Astronautics	China	8	141	17.6

(NP: Number of Publications, TC: Total Citations, ACD: Average Citations per Document).

Among the authors with the highest production presented in Table 8, we find Liao Zhongju (17), followed by Angela Triguero (11) and Chen Jahau Lewis (10). Upon reviewing these authors, we observed that several affiliations coincided with those presented in Table 7, reaffirming that these institutions are important for developing the topic under study. There are recognized authors, such as Serenella Sala and Javier Carrillo Hermosilla, who have many global citations in the documents authored by them identified in the studied repository, which evidences the importance of these authors for tracking the evolution of the topic in future research.

Table 8. Authors with higher production.

Rank	Author	Thematic Areas	Affiliation	NP	TC	ACD	H-Index
1	Liao Zhongju	Business and Economics Environmental Sciences and Ecology Science and Technology	Zhejiang Sci-Tech University	17	707	41.6	21
2	Agela Triguero	Business and Economics Environmental Sciences and Ecology Science and Technology	Universidad de Castilla-La Mancha	11	913	83.0	16
3	Chen, Jahau Lewis	Engineering Computer Science Science and Technology Operations Research and Management Science	National Cheng Kung University	10	367	36.7	19
4	Francisco J. Saez Martinez	Environmental Sciences and Ecology Business and Economics Science and Technology	Universidad de Castilla-La Mancha	10	390	39.0	17
5	Serenella Sala	Environmental Sciences and Ecology Engineering Science and Technology Toxicology	European Commission Joint Research Centre	9	1274	121.6	48
6	Javier Carrillo-Hermosilla	Business and Economics Environmental Sciences and Ecology Science and Technology	Universidad de Alcala	7	995	142.1	12
7	Dominique Millet	Engineering Science and Technology Environmental Sciences and Ecology	Universite de Toulon	7	102	14.6	11
8	Angel Peiro Signes	Environmental Sciences and Ecology Education and Educational Research Business and Economics	Universidad Politecnica de Valencia	7	100	14.3	16
9	Sabina Scarpellini	Business and Economics Environmental Sciences and Ecology Energy and Fuels	Universidad de Zaragoza	7	301	43.0	26
10	Tseng Ming Lang	Engineering Environmental Sciences and Ecology Science and Technology	Asia University Taiwan	7	280	40.0	63

(NP: Number of Publications, TC: Total Citations, ACD: Average Citations per Document).

Table 9 identifies the most cited local authors in the analyzed repository, namely, Jens Horbach, Christian Rammer, and Klaus Rennings, who belong to German institutions. However, most Spanish authors include Angela Triguero, Javier Carrillo-Hermosilla, and Pablo del Rio.

Table 9. Most cited authors.

Rank	Author	Thematic Areas	Country	Affiliation	TLC
1	Jens Horbach	Business and Economics Environmental Sciences and Ecology Science and Technology	Germany	Technical University of Applied Sciences Augsburg	216
2	Christian Rammer	Business and Economics Environmental Sciences and Ecology Geography Engineering	Germany	Centre for European Economic Research (ZEW)	216
3	Klaus Rennings	Environmental Sciences and Ecology Business and Economics Social Issues	Germany	Centre for European Economic Research (ZEW)	210
4	Angela Triguero	Business and Economics Environmental Sciences and Ecology Science and Technology	Spain	Universidad de Castilla-La Mancha	207
5	Javier Carrillo-Hermosilla	Business and Economics Environmental Sciences and Ecology Science and Technology	Spain	IE Business School	201
6	Pablo del Rio	Energy and Fuels Environmental Sciences and Ecology Business and Economics	Spain	Institute for Public Goods and Policies	201
7	Maria Davia	Social Sciences Social Issues Business and Economics	Spain	Universidad de Castilla-La Mancha	184
8	Lourdes Moreno-Mondejar	Environmental Sciences and Ecology Business and Economics Science and Technology	Spain	Universidad de Castilla-La Mancha	184
9	Colin Chi Jyun Cheng	Engineering Business and Economics Operations Research and Management Science	Taiwan	National Kaohsiung University of Science and Technology	181
10	Effie Kesidou	Business and Economics Environmental Sciences and Ecology Social Sciences	United Kingdom	University of Leeds Manchester Metropolitan University University of Nottingham	150

(TLC: Total Local Citations).

These authors focus on environmental science, ecology, business, and economics. However, relevant thematic areas for eco-innovation have been identified, such as energy and fuels, science and technology, public administration, engineering, and social issues. The University of Castilla-La Mancha, previously shown in Table 8, is recognized regarding the institutions.

4.4. What Are the Main Research Approaches and Trends in Eco-Innovation in Manufacturing?

Eco-innovation has been approached from different perspectives. The three-field graph presented in Figure 6 shows some of these perspectives. The right column shows that, in addition to eco-innovation, the most productive authors (located in the central column) study concepts such as green innovation, environmental innovation, sustainability, eco-design, environmental policies, environmental regulation, and circular economies. These connotations or associations of ideas allow identifying topics or areas that have been explored in the past and continue to be explored at present.

Figure 6 also shows the identified seminal documents (shown in the left column). Some of the authors shown in Table 9, such as Horbach, Carrillo Hermosilla, and Cheng C.C.J., can be identified in Figure 6, suggesting that the documents they authored were or are key to formulating and understanding the concept.

The keyword co-occurrence network shown in Figure 7 classifies and modulates the set of keywords used by the various documents that comprise the studied repository, allowing the observation of trends and study topics [54]. The keyword with the highest frequency is eco-innovation, where significant relationships with words such as performance, management, and administration are evident. These words comprise the central theme of the largest cluster (in blue color): corporate management for eco-innovation in the pursuit of competitive advantage [35]. Regarding the other two identified clusters, approaches related to sustainable development, eco-design, environmental impact, renewable energy, environmental management, etc., make up the red cluster focused on studying the production of eco-innovations in artifacts [39]. In the green cluster, keywords such as circular economy, environmental performance, product development, and innovation are identified, focusing on discussing the business transition towards the circular economy [36,43].

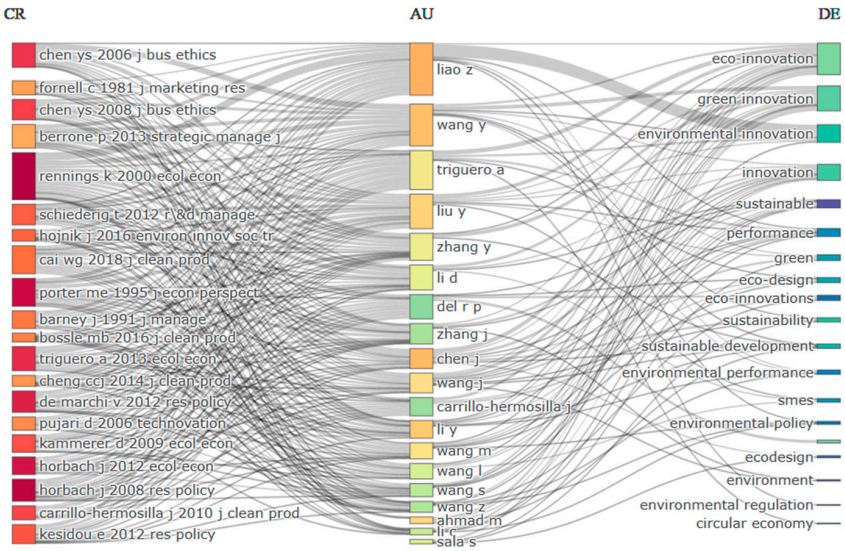


Figure 6. Three-field plot. CR: Most Cited References, AU: Authors with the Highest Number of Publications, DE: Most Used Keywords. Source: Bibliometrix.

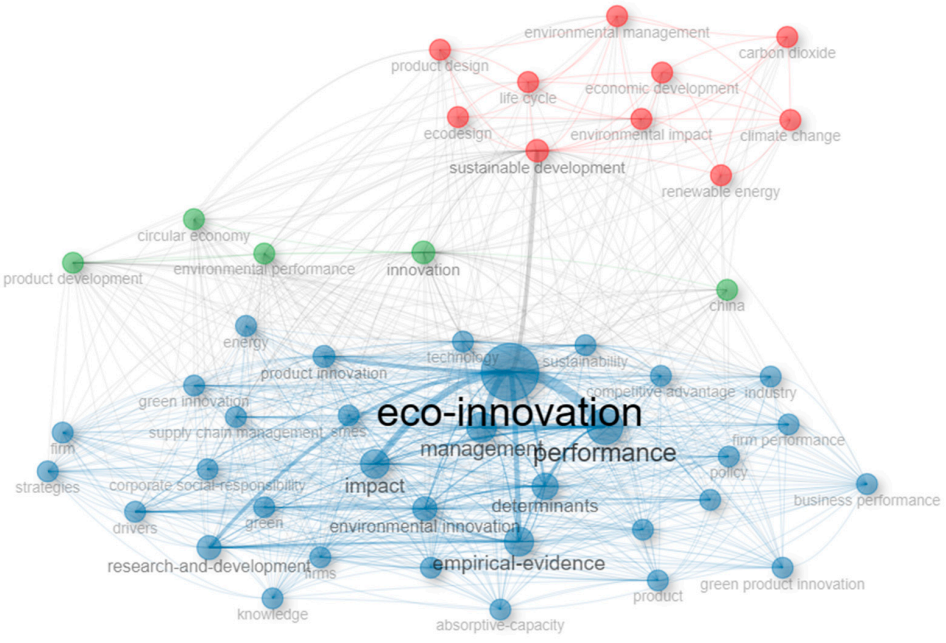


Figure 7. Co-occurrence network between keywords. Source: Bibliometrix.

The co-citation graph in Figure 8 is a valuable tool for identifying highly relevant documents across the research domain. It also allows the identification of the thematic focus of the citations according to the formation of clusters in the network itself [55]. In the blue cluster, we identified the documents that contributed to the theoretical development of the concept. In this cluster, we identified documents by Rennings, Horbach, De Marchi, Triguero, and Porter, also identified in the graph in Figure 8, which discuss the relationship between companies and the environment, the importance of developing improvements in artifacts that consider the environmental variable, and their contribution to the ecological economy.

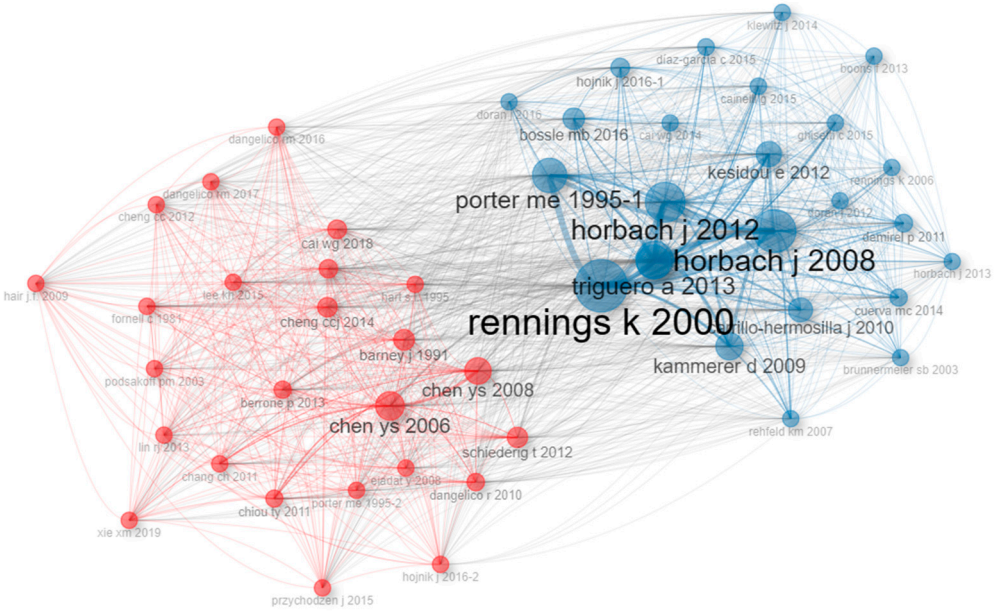


Figure 8. Co-citation network between authors. Source: Bibliometrix.

In the red cluster, documents such as those of Hair, Chen YS, Chen Y, Fornell, Podsakoff, and Dangelico appear. Their focus is the development and empirical application of measurement and validation instruments associated with business activity performance. This result is in line with the findings of Fatma and Haleem [22], identifying the same authors and seminal documents.

The thematic trends graph presented in Figure 9 complements the interpretation of the keyword co-occurrence graph presented in Figure 7 by depicting the evolution and manifestation of the keywords. This figure enhances its interpretation and relevance by elucidating the trajectory growth phases in research domains, as outlined in Sanni and Verdolini [21]. Illustrated by the terms on the y-axis, it is evident that since 2011, eco-innovation has been addressing environmental issues, aiming to integrate technology into industrial adaptation through legislative measures and problem-solving initiatives, culminating in the initial research phase of eco-innovation. By 2015, the discourse on eco-innovation had progressed to examining artifacts using techniques such as life cycle assessment and the TRIZ methodology, which seek to provide tools for analyzing impacts on product and goods design, leading to the concepts of eco-design and product development. Lastly, terms like transition, economic development, performance, and management indicate that the current trend in analysis involves measuring eco-innovation as a business strategy intertwined with firms' competitiveness, driven by shifts in the business landscape and the societal demand for sustainability. Notably, given the exponential growth in publications, eco-innovation is currently experiencing an acceleration phase in line with its research trajectory.

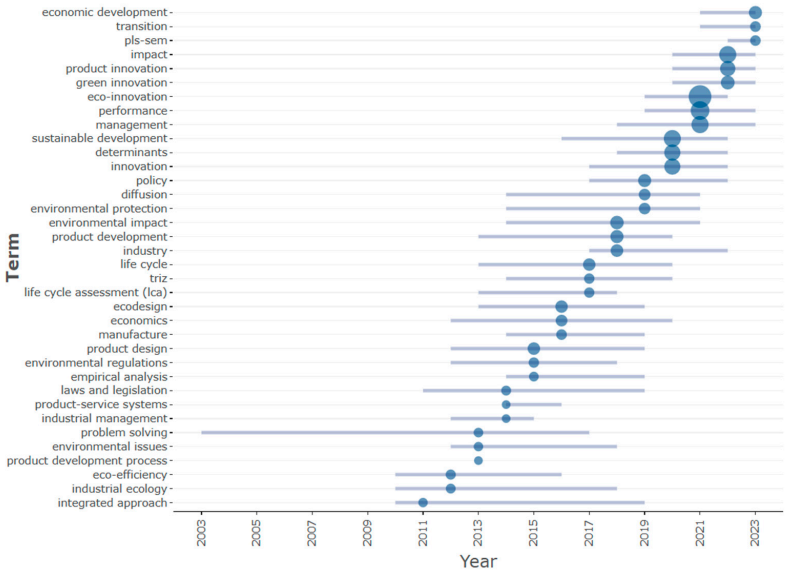


Figure 9. Trends topic. Source: Bibliometrix.

4.5. Which Publications Are Most Relevant from the Selected Databases in Eco-Innovation in Manufacturing?

The most relevant publications were classified according to the average number of citations per year, as presented in Table 10. Among the most significant is "Green Process Innovation, Green Product Innovation, and Corporate Financial Performance: A Content Analysis Method", which focuses on the relationship between the development of eco-innovations and corporate economic performance, with an average of 84 citations per year. "Current Options for the Valorization of Food Manufacturing Waste: A Review" is focused on the food industry and is the second most impactful document identified through the bibliometric analysis, with an average of 69 citations per year. In third place, "Lost in Transition? Drivers and Barriers in the Eco-Innovation Road to the Circular Economy" presents a study directed at the drivers and barriers of EI in the organizational integration of the circular economy as a framework to maximize resource use efficiency.

Table 10. Locally most cited documents identified.

Authors	Countries/ Regions	PY	Title	TGC	TCY	References
Xie, X. et al.	China	2019	Green process innovation, green product innovation, and corporate financial performance: A content analysis method	502	83,67	[56]
Mirabella, N. et al.	Italy	2014	Current options for the valorization of food manufacturing waste: A review	767	69.73	[57]
De Jesus, A. and Mendonca, S.	Portugal	2018	Lost in Transition? Drivers and Barriers in the Eco-innovation Road to the Circular Economy	481	68.71	[58]
Saidani, M. et al.	Francia	2019	A taxonomy of circular economy indicators	412	68.67	[59]
Horbahc, J. et al.	Germany	2012	Determinants of eco-innovations by type of environmental impact—The role of regulatory push/pull, technology push and market pull	874	67.23	[60]
Klewitz, J. and Hansen, E.	Germany	2014	Sustainability-oriented innovation of SMEs: A systematic review	727	66.09	[61]
Ahmad, M. et al.	China	2021	Modelling the dynamic linkages between eco-innovation, urbanization, economic growth and ecological footprints for G7 countries: Does financial globalization matter	264	66.00	[62]
Cheng, Y. et al.	China Finland Australia	2021	How do technological innovation and fiscal decentralization affect the environment? A story of the fourth industrial revolution and sustainable growth	242	60.50	[63]
Chen, Z. et al.	China	2021	Do carbon emission trading schemes stimulate green innovation in enterprises? Evidence from China	241	60.25	[64]
Ding, Q. et al.	China	2021	Towards sustainable production and consumption: Assessing the impact of energy productivity and eco-innovation on consumption-based carbon dioxide emissions (CCO2) in G-7 nations	235	58.75	[65]

(PY: Publication Year, TGC: Total Global Citations, TCY: Total Citations Per Year).

4.6. In What Research Areas Has Work Been Carried out in the Shipbuilding Industry?

As mentioned earlier, when applying the comprehensive search equation, only four relevant documents were identified for the study of EI regarding manufacturing activities and the shipbuilding industry. The information gathered from these documents is summarized in Table 11.

Table 11. Identified studies on eco-innovation in the shipbuilding industry.

Author	Countries/ Regions	PY	Title	Approach	References
Hermann, R. and Wigger, K.	Norway	2017	Eco-innovation drivers in value-creating networks: A case study of ship retrofitting services	To analyze how ship retrofitting services can create value through eco-innovation via a case study. Area: ship servicing.	[66]
Rivas-Hermann, R. et al.	Denmark Germany Netherlands	2014	Innovation in product and services in the shipping retrofit industry: A case study of ballast water treatment systems	Study a business model (product service) applied to ballast water treatment technologies. Area: auxiliary systems and equipment/environmental impact.	[67]
Makkonen, T. and Inkinen, T.	Finland Denmark	2018	Sectoral and technological systems of environmental innovation: The case of marine scrubber systems	Intertwine key innovation concepts and apply them to classify and systematize an environmental product innovation: marine purification systems. Area: environmental impact, R&D, auxiliary systems, and equipment.	[68]
Chica, M. et al.	Spain Australia Norway	2023	Adopting different wind-assisted ship propulsion technologies as fleet retrofit: An agent-based modeling approach	Study the effects of political scenarios on the adoption of wind propulsion technologies, incorporating decision steps for each ship to adopt one of the three modeled technologies. Area: propulsion systems/energy technologies modeled.	[69]

(PY: Publication Year).

These results reflect an evident concern emerging from eco-innovation research within the shipbuilding industry towards the growing demands of an increasingly environmentally conscious sector. Efforts are underway to seek innovative solutions to address environmental challenges and enhance operational efficiency in this sector. However, additional efforts are required to explore this area to maximize the benefits of these initiatives. This entails increased collaboration between academia, industry, and regulatory bodies to drive research and development of more sustainable technologies and responsible business practices.

5. Discussion

The results found in both search engines were processed through the Bibliometrix, Gephi, and Microsoft Excel tools, which allowed analyzing relevant aspects of scientific production using bibliometric techniques. In order to answer the research questions posed, the following factors were identified: (I) most relevant types of publications; (II) behavior of production on eco-innovation in the manufacturing industry over time; (III) most relevant authors, sources, affiliations, and countries in the field of eco-innovation in the manufacturing industry; (IV) articles with the highest relevance based on the index of citations per year; (V) main approaches and trends of eco-innovation in the manufacturing industry; and finally, (VI) the most relevant areas of study in the shipbuilding industry.

1. The answer to the first question (RQ1) was obtained from the table with the total and percentage of each type of document stored in the database. Article-type publications constituted the vast majority of document typology, with more than 80% of the total.
2. Despite the introduction of the concept of EI by [7], the results related to answering the second question (RQ2) reveal that academic production began in 2000 and remained low until 2010. Production began to increase in 2011 and has continued to increase. By 2023, 225 documents related to eco-innovation in the manufacturing industry were

reached, and by 2024, 44 publications were recorded, which, according to the observed trend, is expected to increase during the year.

3. Through indicators such as the H-index, the average citations per year, and the number of documents produced, it was possible to identify the most relevant sources, authors, institutions, and countries, answering the third research question (RQ3). China, Spain, Italy, the United Kingdom, and France are the most influential countries, corresponding to the territories with the most citations. In fifth place in this classification is Germany, which is consistent with the country of origin of the most cited authors, indicating the relevance of this country in the academic field on this topic.
4. Regarding the sources, the journal "Journal of Cleaner Production" from the publisher Elsevier, dedicated to researching the relationship between economic activities and the environment, has an H-index of 60, the highest identified in the analysis. The H-index of the "Journal of Cleaner Production" is almost one and a half times the value of the H-index identified for the "Business Strategy and Environment" journal, which is more focused on the business field (41) and approximately three times the H-index for the "Sustainability" journal (22), which is focused on sustainability-related themes.
5. On the other hand, the institutions observed were the University of Porto, Jiangsu University, Zhejiang University of Science and Technology, and the University of Castilla-La Mancha, whose countries are respectively Portugal, China, and Spain. This joint analysis reveals that the countries that have developed the most outstanding contribution to knowledge regarding the study of eco-innovation in the manufacturing industry are Germany, China, and Spain, with higher impact indices in institutions and authors where members of the University of Castilla-La Mancha and the University of Science and Technology of Zhejiang are recognized through the results obtained in the present scientometrics.
6. Regarding the trends (RQ4), the analysis approach links concepts such as green technologies, green innovation, environmental innovation, product performance, ecodesign, environmental regulations, etc. We have found evidence of a trend towards the study of EI about business competitiveness, the study of market dynamics about the circular economy, the analysis of innovative processes and technical change in artifacts, and the study of government policies and drivers in search of accelerating the economic migration towards sustainability. These research topics are relevant in thematic areas such as environmental sciences and ecology, management, and business, engineering, energy, and fuels, among others identified.
7. From the results of the fifth question (RQ5), in the documents with the highest citations per year, we found "Green Process Innovation, Green Product Innovation, and Corporate Financial Performance: A Content Analysis Method", "Current Options for the Valorization of Food Waste Manufacturing: A Review" and "Lost in Transition? Drivers and Barriers in the Eco-Innovation Road to the Circular Economy", which are within the framework of finance, manufacturing, and economics, respectively, relevant to the research trends found.
8. Regarding question six (RQ6), it is evident that the number of records regarding the shipbuilding industry decreased significantly. The four analyzed documents study topics related to the modernization of ships and more efficient and environmentally friendly technological alternatives for auxiliary systems, proposing ideas such as business models, incentives, policies or regulations, or value creation processes. The articles reflect that among the most latent reasons for introducing eco-friendly technologies are the economic impact and institutional pressures for economic migration towards sustainability in various manufacturing activities and the improvement of commercial dynamics that improve societies' well-being.

In contrast to other reviewed bibliometrics, it was found that the economic factor is key when migrating to other technologies.

The study conducted by Lopez-Perez et al. [15], utilized a smaller sample size, but it provided a more detailed analysis of the keywords found in Figure 7. It discusses the

role of eco-innovation in firms' financial performance by categorizing this cluster into R&D strategies, transitions towards sustainability, impact on firms' performance, and strategic management, along with their facilitators and barriers in their co-occurrence graph.

The documents most similar to the approach taken are those of Fatma and Haleem [22], and Peregrina et al. [70], where there is agreement among seminal authors, institutions, countries, and keywords. In the case of [22], clusters of keywords with more defined thematic centrality are identified, highlighting firm performance, market actors' commitment to social responsibility, and strategies and mechanisms for developing eco-efficient technology as central study themes. This is complemented by [70], who, over three time periods, observed the thematic evolution of eco-innovation, yielding results similar to those presented in Figure 9.

Finally, in [22], the authors identified four categories of seminal authors related to the development of the eco-innovation concept: theory preceding eco-innovation, currently influential authors, and authors intensely studying eco-innovation, along with its diffusion and strategic value in firms. This contrasts with Figure 8, which is divided into authors of theoretical development and influential authors in the current eco-innovation discussion.

Khanra et al. [12] asserted that sustainable development and green innovations are essential as business competitiveness strategies. However, more significant efforts are needed to allow companies to offset the cost of the transition. Similarly, the circular economy becomes a valuable model for these technologies. Martinho and Mourão [17] highlighted the emerging potential of EI in the circular economy while also pointing to the need to complement the relationship to achieve this objective.

Industries such as the automotive industry have more outstanding contributions than the shipbuilding industry, where they have been developing gradually, paving the way for collaboration. Vaz et al. [13] affirmed that this sector mainly comprises incremental innovations due to its low complexity and cost. However, radical innovations are necessary as they allow for rigorous compliance with current environmental standards. The study highlights that emission reduction, life cycle analysis, cleaner production, reverse logistics, and eco-innovation are the most common practices.

The EI in the shipbuilding industry largely depends on the innovation capacity of a wide range of supplier industries, including manufacturing. A collaborative effort is necessary, requiring the integration of different capabilities throughout the supply and value chain, such as systems providers, machinery suppliers, raw material suppliers, component suppliers, and enabling technology providers linking suppliers from industries associated with steel, plastics, textiles, wood, navigation and control systems, and propulsion engine or turbine manufacturing. Based on this, it is possible to consider extrapolating these suggestions to the application in naval industry activities due to the similarity in economic activities. Since EI in manufacturing is a topic that has been little explored, incremental eco-innovations are conducive to the transition toward sustainability. The interest of the naval industry in developing eco-innovations is evident, where artifacts characterized as eco-innovative are already considered and classified through codes such as MARPOL, as adopted in [71].

6. Potential Future Research Trajectories

This bibliometric analysis reveals that although the concept of EI is relevant to the academic literature, it is still incipient, and further exploration and dissemination are needed. Reviewing the seminal and current research documents shows three main study approaches that can continue to be developed over the years: product design and development, environmental policy and transition/regulation mechanisms, and business performance and strategy.

6.1. Research on the Theory and Definition of the Concept

The eco-innovation (EI) concept is part of the environmental trend in the study of organizational innovation, where the aim is to explain the phenomenon of the transfer

and diffusion of forms of knowledge to societies [72], focused on the development of products that reduce or mitigate environmental impacts without compromising well-being or value creation. Two fundamental theories are considered for the study of the concept: the Porter hypothesis and the resource-based view, which is within the current study trend (business management). In addition to existing theories, EI is examined in various contextual dimensions in academic research. These include the business environment, consumer and public perceptions, knowledge-based economies and societies, and the enablers and barriers related to business and social adoption. These studies emphasize reducing the consumption of material and energy resources [73]. However, in [8], there were three additional concepts identical to eco-innovation: environmental innovation, sustainable innovation, and green innovation.

Although sustainable innovation currently includes dimensions related to society and the economy, differentiating it from the other three related concepts [66], future theoretical research should seek a more precise definition, identifying the differences in applying these diverse concepts or unifying them into a single definition.

Nevertheless, it is remarkable that the interest in EI is not only rooted in the study trends of innovation in technology and the phenomenon of social change; in fact, the link between EI, eco-design, and eco-products is noteworthy. These three concepts establish a line of study that can define the identity of the term about the technical change of artifacts, so the exploration under this lens of analysis is suggested, as recommended by previous studies [11–14].

6.2. Application in Product and Service Design and Development

While innovation does not study artifacts but rather the process of their genesis and change, eco-innovation was relevant for the study of product development between 2015 and 2020, as evidenced in Figures 7 and 9. Academic production in this field has declined, focusing on the discussion of organizational competitiveness and the complexity of the innovation process to improve the environmental performance of businesses in business networks and value chains. However, due to the link with eco-design, product development, life cycle analysis, and the TRIZ method, it is suggested to continue exploring eco-innovation and its product identification.

To fill this knowledge gap, future research must focus not only on clarifying concepts and methodologies but also on exploring their practical application. In particular, it is necessary to investigate the issues associated with innovation's dissemination and technological scaling.

Regarding application, challenges are associated with the general dissemination and technological scaling of innovation [74]. Future research could address the concept in its practical application, evaluating the success of innovations in terms of the design of goods oriented towards efficiency and considering technological maturity and the cost of acquiring technology.

6.3. Shipbuilding Industry

As evidenced in the results of RQ6, eco-innovation in manufacturing for the shipbuilding industry needs more research studies, both in terms of processes and products. Considering disruptive and incremental innovations, these innovations must be studied in creating new vessels and modernization processes. Additionally, it is important to consider that the naval industry encompasses both ships and naval artifacts, both for water and marine sources, which can also be the subject of eco-innovations.

Furthermore, research is suggested to evaluate the criteria for decision-making regarding these innovations based on aspects involving the manufacturing, operation, and maintenance of vessels, the assessment of alternatives, their environmental and economic impact, and their adaptability to the environment in which they are intended to be applied.

7. Study Limitations

Several limitations of this study can be addressed in future research. First, although Scopus and the Web of Science (WOS) were used as the primary data sources, these databases may not capture all the relevant scientific production in other languages or less accessible sources, which could restrict the breadth of the analysis and exclude important studies published in databases not widely utilized. For example, other databases and search engines may include specific studies on eco-innovation in the shipbuilding industry that are not included in the databases used.

Second, the bibliometric analysis focused on quantitative metrics such as the number of publications and citations, but it needed to consider the real impact of the studies in depth. Future research could include the application of complementary methodologies, such as qualitative analyses or case studies, to deepen the understanding of how these concepts are developed and applied in different geographical contexts and evaluate the relevance and practical applicability of eco-innovation research within the shipbuilding sector.

Third, although the most influential authors, affiliations, and documents were identified, the geographical concentration of research may reflect a regional bias in the production and dissemination of knowledge about eco-innovation. Future research can explore in greater depth the contribution of other countries and regions to provide a holistic and representative view of eco-innovation at a global level.

Fourth, it is important to note that the database is limited to publications in English, which could bias the results. Other investigations could consider data available in other languages to obtain a more complete global view of eco-innovation.

Finally, this study focused on concepts such as circular economy, eco-design, and green technologies, but other important aspects of eco-innovation, such as public policies, business strategies, and social innovations, were not addressed in depth. Future research should incorporate a broader range of concepts and approaches to provide a comprehensive and multidimensional understanding of eco-innovation in the manufacturing and shipbuilding industry.

8. Conclusions

The search and analysis helped verify the selected topic's contributions. Since its inception, eco-innovation has been perceived as introducing new knowledge forms, such as processes, products, or technologies, whose impact is reflected in reducing environmental harm.

The different authors reviewed have proposed trends according to their area of study; some have addressed parameters, other drivers, and some theories. In this sense, they have demonstrated that eco-innovation is a broad concept that requires research in multiple fields. For example, in the shipbuilding industry, there needs to be more investigations that go beyond the modernization of already-built vessels.

The most widely disseminated type of document is one in which most of the scientific production comes from powerful countries such as China, Spain, Italy, the United Kingdom, France, and Germany.

The results show that the strongest trends are business administration and management, green technologies, eco-design, circular economy, environmental impact, and product performance. Among the most important findings, economic factors and cost compensation are crucial to facilitating the transition towards eco-innovation in the industry. The circular economy emerges as a valuable model for driving eco-innovations.

Adopting eco-innovations in the shipbuilding industry requires a collaborative approach involving various actors in the value chain, from equipment manufacturers and material suppliers to engineering and design services. Additionally, it is essential to promote the research and development of new technologies, materials, and eco-friendly manufacturing processes for the shipbuilding industry.

Implementing incremental and radical innovations in the shipbuilding industry is suggested, taking reference from similar sectors, such as the automotive industry, where the need for collaboration among the different links in the value chain and stakeholders

is emphasized [13]. Based on the above, the bibliometric methodology relating to trends, key players, and challenges suggests the importance of the circular economy, incremental and radical innovations, and collaboration to drive the transition towards more sustainable practices in various industries, including the shipbuilding industry.

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