Friends with Benefits or Enemies – Eco-Innovation and Emerging Technology

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Abstract

Eco-innovation is usually seen as the antipode of technology. The purpose of this research is to explore what the current research streams are and how they are changing over time, aligning and juxtaposing eco-innovation and emerging technologies and addressing this common misunderstanding. The importance of obtaining this high-level overview of the research done comes from the explosion of both research areas in the last 10 years, which highlights their dynamic development and vibrant evolution. To achieve this goal, we perform a bibliometric analysis, basing it on 399 publications indexed in Web of Science. The research questions to be answered are 1.) What is the general scope of research focusing on eco-innovation and emerging technologies simultaneously?; and 2.) What are the tangential themes surrounding eco-innovation and emerging technologies? From these broad research questions, several sub-questions outline the scope of the research and provide a deeper understanding of who the most relevant authors are, which journals publish such research, what the trends in the research topics are so far, and how the research is progressing in terms of growth and direction. The results addressing the second research question reveal some hidden dependencies of the current state of the research relationship and provide insight into some possible directions for future research. The results are relevant and insightful for researchers and practitioners in the fields of eco-technological innovation, sustainability and the environment, and ecological studies. The study concludes by formulating current themes and knowledge gaps for further research, as well as indicating under-researched areas of emerging sub-streams involving ecology, innovation, and technology. Another contribution is the suggestion of formulating a new research stream in the innovation management scientific field: eco-tech innovation..

Index Terms— eco-innovation, environmental innovation, green innovation, emerging technology.

1. Introduction

The growing concern about the planet's environmental future compels scholars from every science area to encourage eco-innovation research. Governments progressively are including regulations to ensure that businesses do not fall behind in aligning their operations with best practices to ensure environmental health in the future [1]. Businesses are also more and more focused on implementing innovations (product, process, organizational, and marketing) aiming at significantly decreasing environmental impact [2]. Meanwhile, emerging technology affects all sectors and leads to drastic changes for all stakeholders, including nature. Technology and technological innovations, in particular, are some of the means of eco-innovation according to some authors [3]. Technology has been argued to be one of the determinants of eco-innovation [4]. For others, technology fosters conventional innovation and not green innovation [5]. The literature also offers the polar view that the technologies applied in eco-innovations are characterized by a higher degree of complexity compared to other innovations, therefore this does not imply a higher short-term value for eco-innovations [6]. The research gap addressed in this study is the lack of intersections between authors dealing with eco-innovation and emerging technologies simultaneously, and how these studies intervene and can be applied when it comes to the common goals of humanity – innovation in the eco field. This study aims at addressing the twofold nexus between eco-innovations and emerging technologies and their manifestations by

conducting a bibliometric analysis to reveal how these two essentials for the global business fields (incl. humanity) are collaborating and intertwining. In this study, we narrow the research focal point to emerging technologies only, which are not the green and cleaner technologies usually investigated in other studies.

The bibliometric analysis in this research reveals the main spheres and categories as well as the evolution in the existing scientific literature between eco-innovations and emerging technologies. Such research has not existed so far and this lack of overview blinds society to the delusion that eco-innovations and technologies are two incompatible and even counterproductive concepts. The formulation of two research questions (RQ) motivated the research and gives answers that might be useful for some less researched topics and knowledge gaps to be addressed in the future.

RQ1: What is the general scope of research focusing on eco-innovations and emerging technologies simultaneously?

From this broad research question, several sub-questions address scope: who are the most relevant authors, which journals publish such research, what are the trending research topics so far, and how is the research progressing in terms of growth and directions.

RQ2: What are tangent topics around eco-innovations and emerging technologies?

The second RQ reveals some not obvious dependencies of the current state of the art of research nexus and gives a clue on some possible directions for future research.

The contribution of this study is the overview of the topic discussing both eco-innovations and emerging technology and proposes some gaps for further research. It also proposes typology by clustering the current research agenda and mapping the research already done in this multidisciplinary scientific field.

2. Theoretical background

In this section of the study, we go through the basic concepts related to the two study objectives to make the scope clearer. To achieve coverage, we step on keywords and the most relevant and cited studies matching our search criteria.

A. Eco-innovations in scope

Eco-innovations is a broad collective term that generalizes many concepts within. However, for making a scope of this research, these keywords are used:

'eco innovation' OR 'eco-innovation' OR 'ecological innovation' OR 'environmental innovation' OR 'green innovation'

The theories of eco-innovation are summed up by Hazarika and Zhang [3] and conclude into these categories: resource-based theory, institutional theory, stakeholder's theory, evolutionary theory, and material-based theory. From their novelty perspective, the same authors consider eco-innovations as more often than not incremental innovations instead of disruptive. Carrillo-Hermosilla, del González, and Könnölä [7] divided these into innovations aiming at eco-efficiency, industrial ecology, or design for the environment. According to Díaz-García, González-Moreno and Sáez-Martínez [8], there are usually different terms in the literature summarizing the

concept of eco-innovation and they are usually associated with a reduced negative impact on the environment: “green”, “eco”, "environmental" and "sustainable". In this study, however, we omit “sustainable” because it has been used in many other contexts and, from a methodological point of view, may confound the results of bibliometric analysis.

Hojnik and Ruzzier [9] generalizes the motivation for eco-innovation into reasons related to regulations, market pull factors, EMS, and cost savings. The authors also identified a positive correlation between the motivation of companies to develop eco-innovations and their size. On the other hand, some research reveals that eco-innovation can be a result of organizational motivation for achieving higher organizational performance [10].

The last emerging and most researched topics are related to technologies [11], and different strategies for adoption, incl. open innovation [12] and collaboration [13]; and governmental and institutional support.

B. Emerging technologies in eco-innovations

The emerging technologies in this study are analysed as an adoption strategy for developing and implementing eco-innovations. In the scope of the study fall these common emerging technologies, most recognized in the innovation management literature:

‘AI' OR 'big data' OR 'virtual reality' OR 'augmented reality' OR 'internet of things' OR 'robotics' OR '3D printing’

Some of these technologies were discussed by Kuo and Smith [11] but were only limited to their adoption and application for sustainability goals. Here below we summarize the most prominent research on each of these technologies in the context of eco-innovation.

Table 1 Emerging technologies in the context of eco-innovations

Emerging technology in the context of eco-innovations	Authors/study	Context of application
Artificial intelligence	Effie Kesidou, Despoina Filiou, and Lichao Wu, 2022 [14]	artificial intelligence policies
	S.K. Jha, J. Bilalovic, A. Jha, N. Patel, H. Zhang, 2017 [15]	renewable energy and electrical energy for reaching higher efficiency
	S.M. Zahraee, M. Khalaji Assadi, R. Saidur, 2016 [16]	forecasting energy consumption
	Yunpeng Sun, Ozlem Ates Duru, Asif Razzaq, Marius Sorin Dinca, 2021 [17]	Exploration of pollution through AI
	S. Negny, J.P. Belaud, G. Cortes Robles, E. Roldan Reyes, J.	AI as a problem solving method

	Barragan Ferrer, 2012 [18]	
	Montresor, Sandro and Vezzani, Antonio, 2022 [19]	investments in AI as the greater eco-innovation impact is expected from Artificial Intelligence
Big data (incl. data analytics)	T. Papadopoulos, A. Gunasekaran, R. Dubey, N. Altay, S.J. Childe, S. Fosso-Wamba, 2017 [20]	Measuring performance
	M.H.U. Rehman, V. Chang, A. Batool, T.Y. Wah, 2016 [21]	Measuring performance
	S. Lee, R.D. Klassen, 2008 [22]	For adopting eco-innovation
	M. Song, L. Cen, Z. Zheng, R. Fisher, X. Liang, Y. Wang, D. Huisingh, 2017 [23]	Measuring performance
	Munodawafa, R.T.; Johl, S.K., 2019 [24]	big data technology provides firms the opportunity to obtain information for eco-innovations
	Russell Tatenda Munodawafa, Satirenjit Kaur Johl, 2018 [25]	Big Data Usage towards firm performance
Internet of things (IoT)	J. Lanza, L. Sánchez, L. Muñoz, J.A. Galache, P. Sotres, J.R. Santana, V. Gutiérrez, 2015 [26]	Recognizing faster customer needs by instant feedback
	E. Benkhelifa, M. Abdel-Maguid, S. Ewenike and D. Heatley, 2014 [27]	IoT impacts all aspects of society
Virtual Reality (VR)	Mario Rojas Sánchez, Pedro R. Palos-Sánchez, Felix Velicia-Martin, 2021 [28]	Eco-friendly performance in national parks.
Robotics	Seyed Hamidreza Ghaffar, Jorge Corker, Mizi Fan, 2018 [29]	Additive manufacturing technology and its implementation in construction as an eco-innovative solution

Still, eco-innovation and the application of emerging technologies are extremely under-researched areas [11]. Some of the applications are only in the phases of ideas and gaps identification for further development of eco-innovations (specifically AI, machine learning, and big data). More explorative studies are required and consequently, systematic reviews of the case studies in the literature. However, for the purpose of the overview of the most common emerging technologies, this study applied a bibliometric analysis.

3. Research design

The methodology in this research is selected to be bibliometric analysis as a method covering a large scope of research production and capable of answering our research questions by providing an accurate representation of the current state of the literature on the multidisciplinary topics of eco-innovations and emerging technologies. The selection of the scope was generated by applying a Boolean search in Web of Science (WoS) resulted in 399 publications. The formula used was as follows:

Topic 'eco innovation' OR 'eco-innovation' OR 'ecological innovation' OR 'environmental innovation' OR 'green innovation' AND topic 'AI' OR 'artificial intelligence' OR 'big data' OR 'virtual reality' OR 'augmented reality' OR 'internet of things' OR 'robotics' OR '3D printing'

The results were limited to Social Sciences Citation Index (SSCI) only. The used words originated from the most cited publications on the topics of eco-innovation and emerging technologies when these topics were researched independently. In the process of cleaning the publications in scope, all reviews and editorials were withdrawn, leaving only articles, book chapters, and reports for the bibliometric analysis, amounting to 317 publications from 166 sources, contributed by 1102 authors. The timespan is from 1995 to 2022 (data extraction in July 2022). Because of the interdisciplinary of the scoped topics, only 9% of the publications were single-authored. The internationalization of the research in scope demonstrates a high international percentage of international collaboration amounting to 40% of the publications. The annual growth rate of the publications is 17%, which demonstrates the increasing interest of researchers.

For analyzing the data, R Studio and the Bibliometrix package were used. The same approach has already been used for encompassing Open eco-innovation research [12] in the field of eco-innovations and by Chiu, Liu, Muehlmann, and Baldwin [30] in the field of emerging technologies. It has been also in an increasing number of studies globally because of the potential of such publications to reveal the status quo and further developing areas of research, specifically when the research domain is multidisciplinary. The use of bibliometrics enables researchers to examine the body of literature with a broad scope in order to identify major themes [31].

For addressing the research questions, these bibliometric analyses are used and the results are presented and discussed in the next sections of this study: co-word analysis, dendrogram clustering, factorial mapping, and thematic mapping.

4. Results

A. Co-word analysis

The first analysis is focused on the wording and the combination of different words in research titles, abstracts, and author keywords. Co-word analysis is a tool for describing the network and interactions between the uses of different terminology simultaneously within large research data (publications) [32].

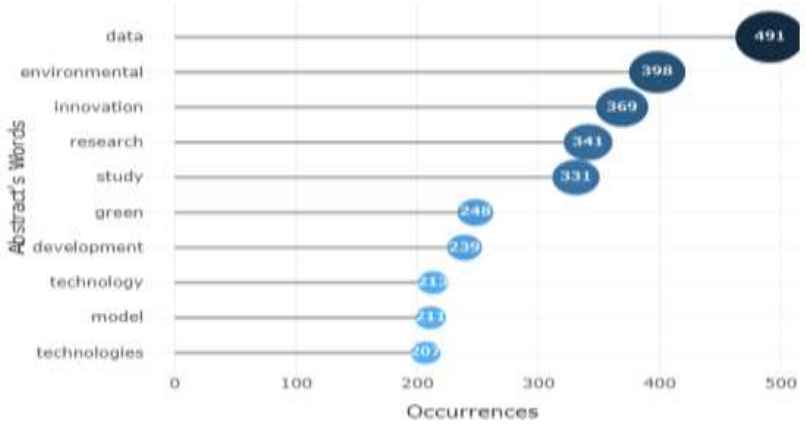

Figure 1 Co-Word (single word) in abstracts

Fig. 1 shows the single words most used in abstracts within the research scope. Having in mind the keywords used for collecting the data, all the words do not reveal new hidden conceptual interrelations except of the word 'model'. All of the rest are basically part of the keywords of the formula for the Bolean search. However, data is mentioned in most of the research and this gave us the assumption that it may be one of the clusters/directions of all the research area (RQ1 and RQ2).

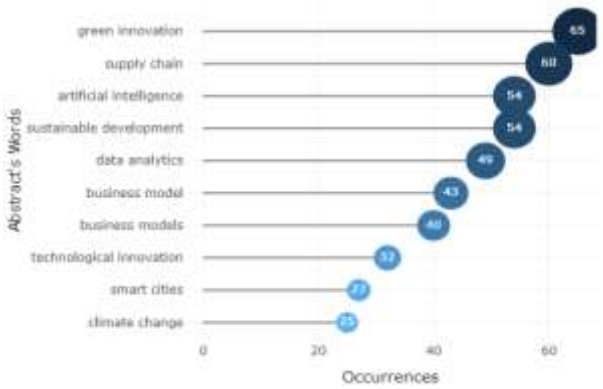

Figure 2 Co-Word (bigrams) in abstracts

The occurrence of words as two-word terms in the research scope is shown in Fig. 2. It discloses some major areas of studies (we focus on those not matching the keywords with which we performed the data selection): supply chain, sustainable development, business model, smart cities and climate change.

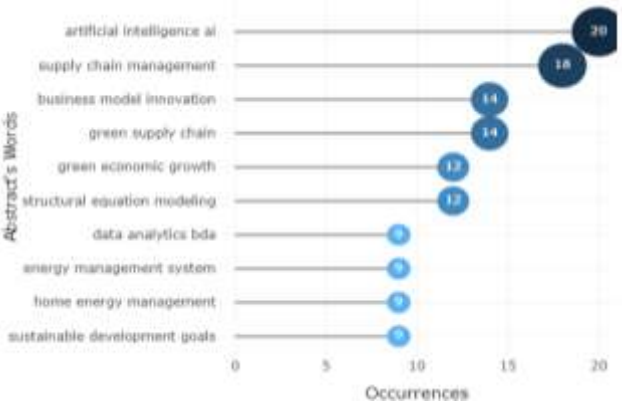

Figure 3 Co-Word (trigrams) in abstracts

The occurrence of words as two-word terms in the research scope is shown in Fig. 3. Supply chain management, business model innovation, green supply chain, green economic growth, structural equation modeling, energy management system, home energy management are among the areas of research with the greatest focus.

In addition, we performed co-word analyses of author keywords, which demonstrated that firm performance through emerging technologies is amongst the main goals of this interrelation between eco-innovation and emerging technologies. It was also confirmed that big data, data analytics and AI were the technologies most researched generally for achieving digital transformation and cost optimization.

In titles co-word analysis, the same trends divulged the orientation of recent research towards data analytics, supply chain models, business analytics for monitoring, and the circular economy. Insightful results came from the trigrams co-word analysis of titles, which revealed along with the already mentioned increasing research in the field of air pollution control, mobile augmented reality, the Fourth industrial revolution, and social media analytics.

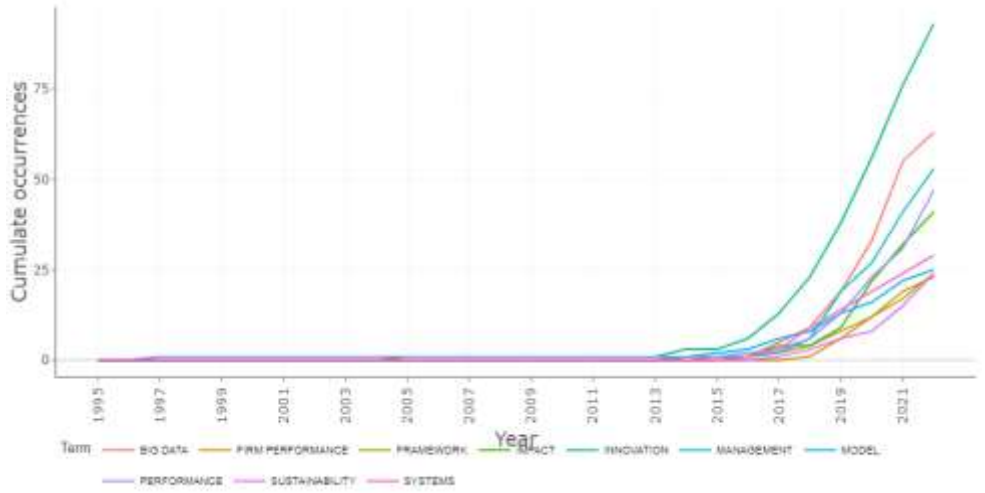

Figure 4 Cumulative occurrences of words in the area of eco-innovation and emerging technologies

The cumulative co-word analysis discloses the extraordinary growth that such research topics experienced after 2016 and 2017. The green line in fig. 4 shows that most of the research and the growth in this research area is related to innovation no matter if this innovation binding to sustainability, firm performance, or emerging technologies. This outcome may give the suggestion of a new general area of innovation management science: eco-tech innovation.

B. Topic dendrogram analysis: clusters reveal

The Topic dendrogram analysis clusters the main topics discussed in the field. The main identified clusters are initiated by information technology science and generally, they divide into technology adoption research (small cluster) and innovations (essential cluster) in the area of the eco context with the use and application of emerging technologies. Thus, the outcome of this topic dendrogram analysis confirms the suggestion of formulating an increasingly growing research area within innovation management: eco-tech innovations.

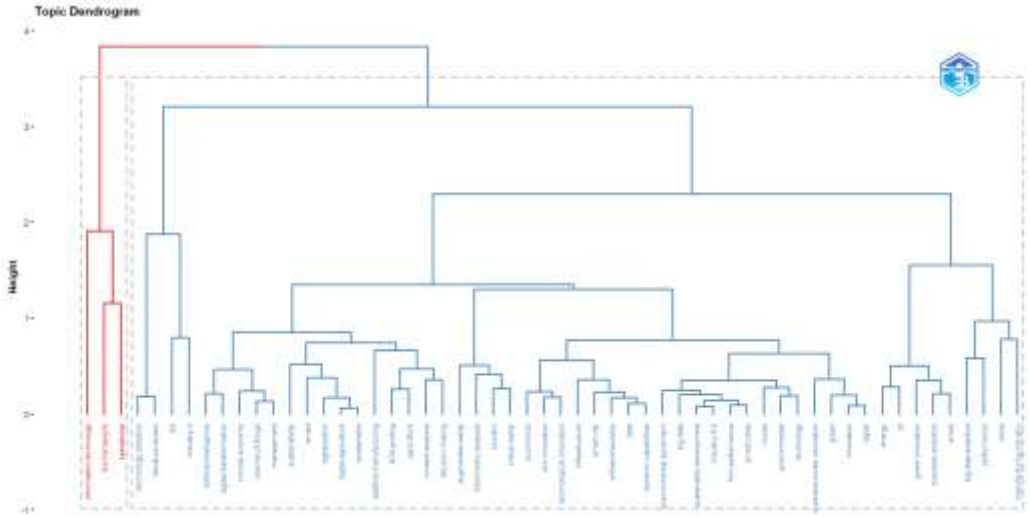

Figure 5 Topic Dendrogram analysis

Some other results identified from the thematic dendrogram analysis are the industries where such eco-technological innovations are largely explored, such as tourism, smart cities, and infrastructure. Interestingly, eco-technological innovation has been studied quite a bit in the context of small and medium-sized enterprises, only one country has emerged as representing the macro-level analysis, and that is China.

C. Factorial map

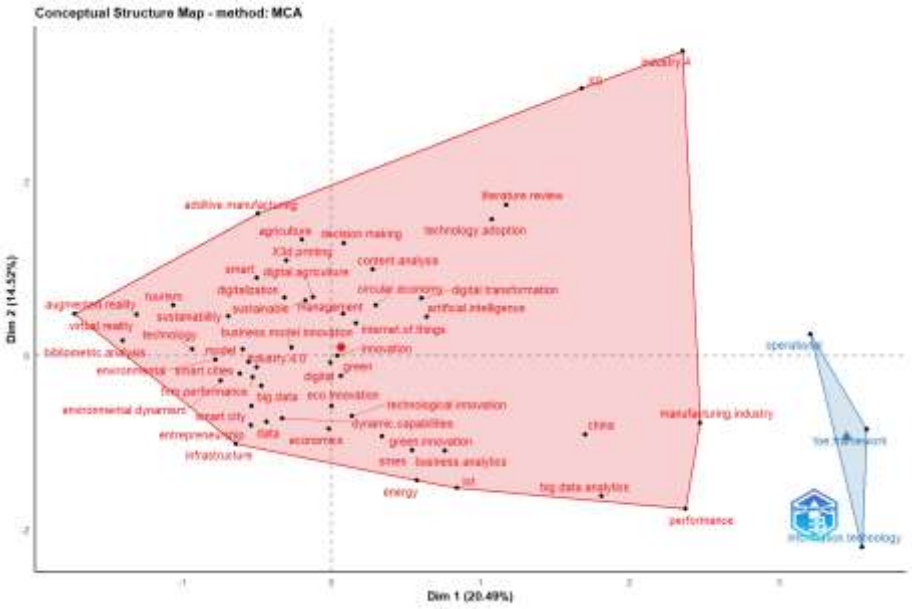

Figure 6 Factorial map through the method MCA

Fig. 6 presents a conceptual structure map through the Multiple correspondence analysis (MCA) method which is a graphical technique minimizing distances between connecting points in a graph plot. Persuading the research questions of this study, we can conclude that the conceptual structure map in fig. 6 gave us reasons to summarize some pre-cluster information of organizing the research in the field: Industry 4.0, firm performance, technology-pull research, and technology-push research all these for achieving the sustainable goals of companies.

D. Thematic map

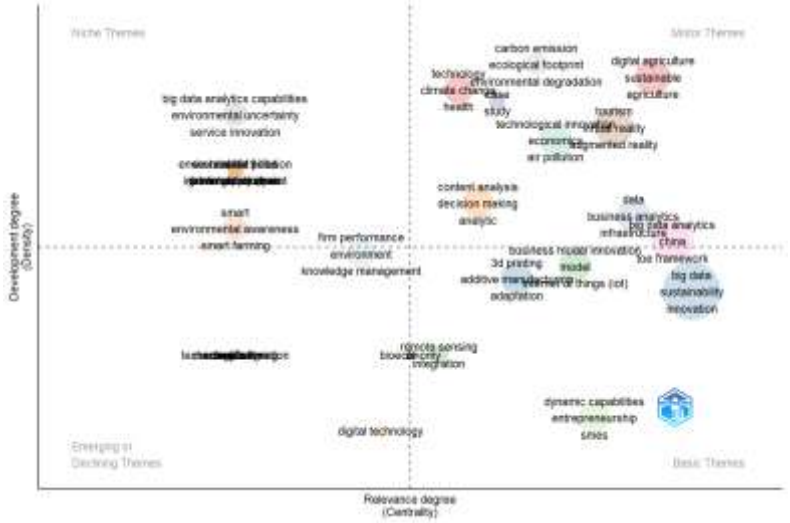

Figure 7 Author keywords – Thematic map

The thematic map divides the themes researched within the scope into four quadrants (clusters of words) according to their centrality and density rank values along two axes. Motor themes are those that are well developed and that is key to the construction of the research field and are characterized by high centrality and high density. The motor themes in the area of eco-innovation and emerging technologies are carbon emission, ecological footprint, air pollution, technology innovation, health, climate change, and environmental degradation. Industries, part of the motor themes are tourism and agriculture, a country – China. This analysis suggests that all other industries are under-researched for the potential of eco-tech innovations application.

Niche themes are internally well-developed and very specialized themes, but marginal in the overall field. In this study's context, these are big data analytics capabilities, environmental uncertainty, service innovation, environmental awareness, and firm performance. This outcome of the research contributes to all researchers searching for a knowledge gap in the field.

Peripheral themes comprise both emerging and declining themes, characterized by low density (underdeveloped) and centrality (marginal), and those that are poorly developed and marginal and mainly represent emergent or disappearing themes. Digital technology and technological innovations are such topics.

Transversal and general, basic themes correspond to themes with high centrality and low density, which are important for the co-production field but are still not well developed. Dynamic capabilities, entrepreneurship, small and medium enterprises, big data, and sustainability are all such topics that can already step on well-developed research.

5. Discussion and conclusion: Main clusters for future research in the field of Eco Innovations and Emerging technologies

Eco-innovation is still a young area of research (Díaz-García, González-Moreno, and Sáez-Martínez, 2015) and thus such bibliometric analysis has the potential to give clear directions for research. We conclude from the performed bibliometric analysis that the term of eco-tech innovation is highly needed as part of the theory so as this particular area of multidisciplinary

research combines eco-innovations with the means of emerging technologies to be smoothly developed.

A. Eco-tech Innovation

Eco-tech innovations are all themes concerning topics related to both eco-innovations and emerging technologies involved. In this study, we thoroughly went through different existing, well researched, under-researched, and totally emerging topics related simultaneously to both research streams. As a result, we can formulate the following main clusters of research (both existing and developing) in the new field of innovation management science called Eco-tech innovations.

Currently, Eco-tech Innovations have been mainly studied in only a few industries, which are tourism, agriculture, and infrastructure (incl. smart cities). No matter the broad range of emerging technologies involved, mainly big data and AI have been within the research focus so far leaving under-researched the application of augmented and virtual reality, IoT, and robotics. With this research, we are calling for further research and case studies that can encompass the practice in such an application and bring more value to the body of knowledge related to Eco-tech Innovations.

The bibliometric analysis over 317publications indexed in WoS gave arguments for the following clusters to be formulated as further areas of developing Eco-tech Innovations (out of the technology-based focus that could step on certain technologies): 1.) Data-drive co-innovations; 2.) Supply-chain eco-innovations; 3.) Business Model Eco-innovations.

B. Data-driven eco-innovations

In this cluster: technologies all the sub-themes of data analytics, data mining, and big data are incorporated for bringing more development of eco-innovations. However, big data has been largely used as a means of researching different aspects of eco-innovation development and management as well as some close concepts to their existence as the risk for example [33]. Another example is a study about the impact of big data technical skills on achieving Business Model Innovation [34]. The multidisciplinarity of research can be seen even within the clusters as the study about Factors Influencing the Adoption of Big Data Analytics in the Digital Transformation Era reveals [35]. Purely from an eco-innovation point of view, several aspects of ecology have been discussed in the literature so far such as eco-efficiency, national eco-innovation policy, and standards, environmental management benefits from multi-relationship social networks, Green Human Resources Management, green finance under big data, Fostering green innovation for corporate competitive advantages, etc.

C. Supply-chain eco-innovations

Supply-chain is the area of business management mostly affected by eco-innovations and emerging technologies as being the most obvious field for optimizations. This is why it deserves a separate cluster additionally impacted by other factors such as Covid-19 and the need for alternative solutions. In the context of eco-innovations and emerging technologies, supply-chains have been studied in the fields of urban sustainability transitions in China [36], barriers of circular food Supply chains [37], the future of supply chains as a consequence of digital technology and circular economy practices [38], etc.

D. Business Model Eco-innovations

Sustainable business models for developing or managing innovations are a new most novel and still under-researched cluster. It was researched in the field of life science [39]. Another multidisciplinary research touching on business model eco-innovation is about digital business model innovation based on an emotion regulation lens [40], contributing insights from the fields of management, technology, and psychology. Business continuity of business models, data network effects in business models, and the combination of food supply-chain challenges solved by business model innovation are just a small number of the newly researched topics in this cluster.

In conclusion, this research provides a series of under-researched topics around eco-innovations and emerging technology. Because of this research, the term eco-tech innovation in the domain of innovation management science is proposed and a call for research in this particular area (supported by special issues of leading journals) may be the next call for action that could support these emerging research fields.

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