Can University-Industry Partnerships Foster Sustainable Development? A Bibliometric Perspective

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Abstract. *The main purpose of this paper is to analyze the interest in the field of university-industry partnerships for sustainable development. The research methodology involves conducting a bibliometric analysis based on a quantitative research method, in the form of an inventory of publishing activities in the chosen field for study. The analysis consisted of querying the database available on the Web of Science platform, which includes journals, scientific papers, books, and other documentation. The query resulted in displaying a total of 65 scientific documents existing in the database. The results obtained from the analysis of the data collected from Web of Science using VOSviewer software highlight the most cited articles, journals, and authors, as well as the existence of strong connections between universities and industries for sustainable development. The United States and China have been the primary producers of publications in this domain, each with seven works, followed by Australia (4) and England (3). The keyword-based analysis highlighted frequently used terms such as "University-industry collaboration," "sustainability," "triple helix," "management," and "innovation." The most cited author in this field is Etzkowitz H. from the International Triple Helix Institute in the United States, and one of the most cited articles is co-authored with Zhou, C.Y. from Hohai University, proposing a Triple Helix model of university-public-government for sustainable development, complementing the university-industry-government Triple Helix for innovation. This bibliometric analysis not only emphasizes the present but also tracks the evolution of researchers' areas of interest in the field of the university-industry relationship for sustainable development.*

Keywords: university; industry; sustainable development; bibliometric analysis

JEL Classification: Q01, O33

1. Introduction

In the current era, marked by major challenges related to climate change, natural resource degradation, and the imperative of sustainable economic development, the close relationship between universities and businesses becomes a key element in ensuring sustainable development. This collaboration not only reflects the evolution of how society addresses environmental issues but also represents an essential mechanism for generating and implementing innovative solutions needed to confront the complex challenges we face both presently and in the future.

Universities, as centers of knowledge and innovation, become the driving force propelling progress in the field of sustainable development. Through advanced research and education focused on environmental issues, these institutions are capable of generating solutions and shaping young professionals ready to tackle

sustainability challenges. (Sisto & López, 2015; Bellei, Poblete, Sepúlveda, Orellana & Abarca, 2013)

Simultaneously, close collaboration with businesses brings the practical and applied dimension of academic research, facilitating the transfer of knowledge and technologies into the real world. Thus, universities become catalysts for innovation, and businesses become essential partners in implementing solutions developed in the academic realm. (Azagra-Caro & Consoli 2016)

In a context where the impact on the environment and natural resources becomes increasingly urgent, the university-business collaboration becomes a pillar of sustainable development strategies. This relationship not only contributes to finding viable solutions to environmental problems but also to the training of a workforce prepared to address sustainability challenges in various economic sectors. As global awareness of the imperative to tackle climate change grows, numerous organizations are pledging to diminish their environmental footprint and actively contribute to a sustainable future. Nonetheless, accomplishing these objectives goes beyond merely establishing targets and adopting new technologies. It necessitates a workforce possessing the skills and knowledge essential for steering the shift towards a greener and more sustainable business model. This is precisely where the concept of employees' green upskilling becomes crucial.(Genghini, 2023)

Thus, the current importance of the relationship between universities and businesses cannot be underestimated, as this collaboration not only facilitates technological and scientific progress but also ensures that sustainable development becomes a tangible and viable reality for current and future generations.

The predominant body of literature addressing industry–university relationships relies heavily on empirical methodologies such as case studies, quantification of patents generated, bibliometric analyses, or extensive surveys (Fontana et al., 2006; Abramo et al., 2009). Notably, some literature underscores the positive impact of scientific outcomes on the economic domain (Beise and Stahl, 1999) and elucidates how numerous innovations would be unattainable without the significant contributions of academics. Another facet of the literature investigates the importance of academics, particularly from an industry perspective, as an external fount of information for novel ideas and the completion of innovations (Fontana et al., 2003).

Given these aspects, we consider it necessary to conduct a bibliometric analysis on university-industry partnerships for sustainable development. Through this analysis, we aim to highlight the volume, impact, and evolution of scientific works in this field, emphasizing the significance of this partnership and the outcomes achieved by various researchers in their respective works. Such an analysis will yield significant benefits in terms of assessing and guiding research, identifying trends, sources of influence, and directions for future development.

In the following sections, we will explore the evolution of research in the field of university-industry partnerships for sustainable development, identifying trends and significant contributions of researchers and institutions. Through this analysis, we aim to highlight the increasing importance of the university-industry relationship in the context of sustainable development and to identify research gaps to guide future research efforts and policies in this vital area for the future of our planet.

Our bibliometric analysis will focus on four main directions and aims to answer the following questions: In which journals are the works on the chosen topic published? Who are the relevant contributors in researching the analyzed relationship? From which countries are the authors (countries of origin)? What are the keywords of these studies? How are these works cited in the literature?

Thus, through the conducted analysis, we will highlight the most cited articles, journals, and authors. We will also analyze the most frequently cited keywords and their evolution over time to demonstrate the temporal evolution of interest in the

analyzed field. In addition to the bibliometric review, we will summarize and synthesize the content of the most cited articles briefly to provide an overview of the content of these articles and offer researchers insight into the field and the main topics addressed in this literature.

2. Materials and methods

In this article, a bibliometric analysis was conducted using the VOSviewer software to meet the analytical needs of various entities such as countries, institutions, journals, and authors. This tool proved instrumental in highlighting the evolution of the influence of university-industry partnerships for sustainable development. Based on the analysis, bibliometric maps were generated to facilitate the examination and understanding of relationships and interconnections among various elements in the field of scientific research, such as articles, authors, keywords, or research areas.

The data used in this analysis were extracted from the Web of Science database. Considering two concepts within the thematic scope of the Web of Science, namely universities and industry, searches were performed for articles, papers, and book chapters that analyze collaborations between these entities. The Web of Science database provided 1626 academic works related to these topics. From these, we selected articles specifically addressing the significance of this partnership in sustainable development, narrowing down the number of articles and papers to 65. The data, including records and references, were collected through a .txt file, which was later uploaded into the VOSviewer software for analysis.

The procedure used in identifying works for bibliometric analysis consists of the following steps:

1. Searching in Web of Science-Clarivate for the main subject "university-industry partnership for sustainable development": The first phase involves conducting a detailed search within the Web of Science-Clarivate platform, focused on the main subject.
2. Extracting the found results: After identifying relevant results, they were extracted to obtain an appropriate list of academic works.
3. Inputting data into VOSviewer: The extracted information, including records and associated references, was collected in a .txt file. This file was subsequently loaded into the VOSviewer software, providing the necessary data for bibliometric analysis.
4. Analyzing data according to multiple criteria: After loading the data into VOSviewer, the analysis was conducted considering various relevant criteria. These criteria may include, but are not limited to, the frequency of occurrences, connections between different works, and others.

3. Results and discussion

This paper aims to present information from the literature, highlight the publication year of the majority of the research, identify authors dedicated to analyzing the relationship between universities and industry with an impact on sustainable development, identify collaborations between co-authors based on their countries, analyze research trends in this field using keywords, and ultimately, showcase the most cited works and rank journals with the most prolific publishing activity.

By addressing key research questions, namely: "In which journals are the works on the chosen topic published? From which countries are the authors (countries of origin)? What are the keywords of these studies? How are these works cited in the literature?", the presentation continues with the analysis of articles using the information provided by Web of Science and the exposition of the results of the

bibliometric analysis, organized into the following categories:

- Description of literature data.
- Publication activity by author.
- Publication activity by country.
- Co-occurrence of keywords.
- Analysis of the most cited works.

3.1. Description of literature data

The selected set of publications is diverse, encompassing a variety of formats and types of works in the field of university-industry collaboration for sustainable development. Table 1 illustrates the types of publications among the total of 65 documents published in the research areas included. According to the table, the majority of publications are articles (37 in total), representing 57%, followed by 27 conference papers (42%). Additionally, there are 3 review articles and 1 book chapter. Therefore, there is a diversity of publication types reflecting the complexity and breadth of the research. However, we believe that a thorough analysis of these information sources is necessary to identify potential directions for future research.

Table 1: Publication type

Type	Number
Article	37
Proceeding paper	25
Review Article	3
Book Chapters	1
Early acces	1

Source: Own processing, using data provided by WOS (Web of Science).

Interest in researching the collaborative relationship between universities and the industrial sector with implications for sustainable development emerged late, in 2010, and fluctuated in terms of the number of publications from year to year, reaching its highest level in 2021 (12 works). Regarding the citations of these articles, an increased interest in this field is observed, particularly after 2018, with a noticeable upward trend in citations over the last 4 years (Figure 1).

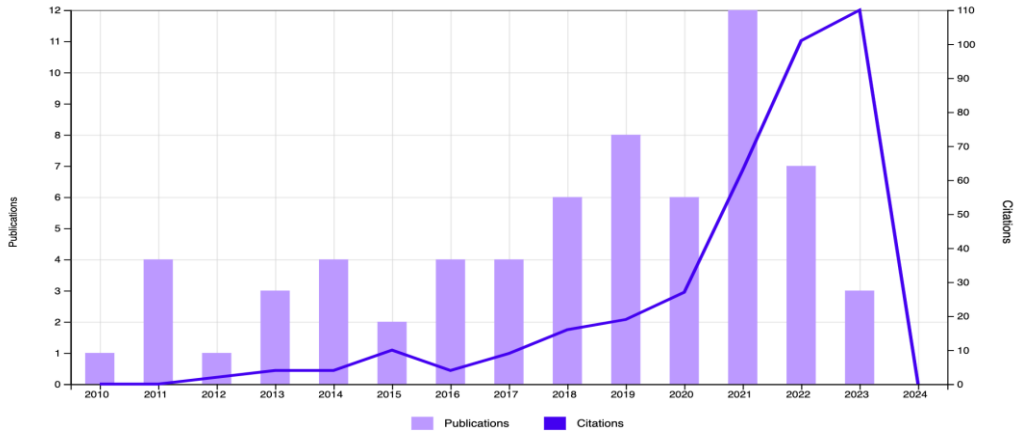

Figure 1: Annual publications and citations

Source: Own processing, using data provided by WOS (Web of Science).

These statistics highlight that research on the collaborative relationship between

universities and the industrial sector with implications for sustainable development has gained prominence and increased interest, particularly after the COVID-19 health crisis, during which the interest in analyzing the benefits of such collaboration has seen a rise.

Research in the field of the collaborative relationship between universities and the industrial sector with implications for sustainable development covers various directions, as highlighted by specialized literature from multiple domains. Figure No. 2 illustrates the top 10 thematic areas identified through publications that address the aforementioned relationship. "Education Educational Research" is the domain with the most publications (18), representing 28%, including research focusing on changes in the educational field to meet the needs of the industrial sector. It is followed by "Green Sustainable Science Technology" (17) and "Environmental Sciences" (14), encompassing articles that emphasize the effects of university-industry collaboration on technology and the environment.

Figure 2: Research areas

Source: Own processing, using data provided by WOS (Web of Science)

This distribution indicates that studies regarding the collaborative relationship between universities and the industrial sector with implications for sustainable development span a broad spectrum of fields, covering technological, environmental, educational, management, and business aspects. This diversity reflects how researchers and professionals explore and investigate this relationship from various perspectives.

3.2. Publication activity by author

The analysis of author co-citations has provided the opportunity to identify the most cited authors in the analyzed field, examining both author citations and co-citations in publications. Graphical representations obtained through the VOSViewer application enable the highlighting of the most influential authors in this domain, serving as valuable support in the documentation process. Figure 3 presents the co-citation map, with authors as the unit of analysis. By setting the minimum number of citations per author to 5, 25 authors meeting this condition were identified out of a total of 2,198. The larger the node (circle), the more cited the author. Additionally, it is important to note that the thicker the connection between nodes, the stronger the connection, and the co-citations of these authors are more frequent. These authors

were grouped into 4 clusters: (red, green, blue, and yellow).

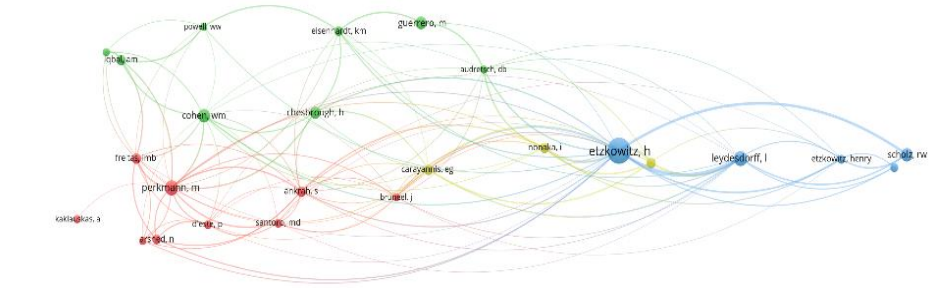

Figure 3: Co-citation of authors
Source: Own processing using VOSviewer, 2023

Therefore, based on this analysis, we can address one of the research questions Who are the relevant contributors in the study of the analyzed? by identifying authors with the greatest impact in this field, relying on the number of citations. This ranking includes names such as: Etzkowitz, H., Eydesdorff, L.; Perkmann, M.; Scholz, R.W.; Cohen, W.M. and Guerrero, M.

3.3. Co-occurrence of keywords

Figure 4 illustrates the graphical representation of the keyword map used by authors, with a minimum keyword occurrence threshold set at 3. This representation reveals a wide diversity of terms proposed by authors in this field, reflecting a variety in specialized literature. Only 8.6% of these terms are found in at least 3 works. The most frequently encountered keyword is "innovation," appearing 17 times and having 54 connections to other keywords such as "University-industry collaboration," "sustainability," "triple helix," "management," etc., being most frequently used in 2018. "University-industry collaboration" ranks second in the most used keywords in the analyzed studies, with 13 appearances and 42 connections to other keywords such as "innovation," "sustainability," "sustainable development," "artificial intelligence," "research-development," etc., being most frequently used in 2020. "Sustainability" is the third most common keyword proposed by authors, appearing 9 times and having 30 connections to other keywords such as "innovation," "university-industry collaboration," "industry," "triple helix," "management," etc., being more frequently used in 2020.

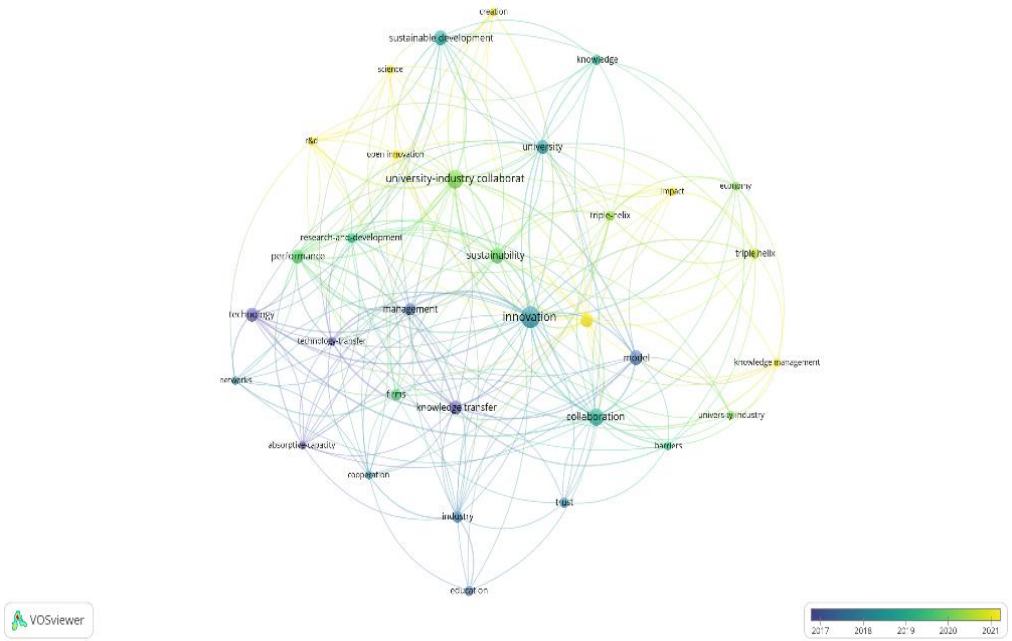

Figure 4: Co-occurrence of keywords
Source: Own processing using VOSviewer, 2023

Through this analysis, besides highlighting the most used terms, we can also observe their evolving trends, providing insights into the future directions of studies. Thus, if in 2017, in studies on the university-industry relationship from the perspective of sustainable development, authors focused and used terms such as "knowledge transfer," "technology," "education," starting from 2020, the emphasis shifted towards terms like "innovation," "sustainability," "triple helix," "knowledge management," "creation."

3.4. Publishing activity by country

The increased scientific interest in researching the relationship between universities and industry in the context of sustainable development reflects a growing awareness of the crucial role this collaboration plays in innovation, knowledge transfer, and addressing complex societal challenges. This heightened attention stems from the necessity to tackle current challenges, ranging from climate change to economic sustainability, through strategic partnerships between the academic sector and industry.

Depending on the level of awareness of these factors and the financial resources available for research, the number of publications varies from one country to another. Figure 5 illustrates the map of countries that have investigated and published works on the university-industry relationship. The number of these publications ranges from 1 publication (light blue) to 136 (dark blue). According to the map in Figure 5, the most publications over time were produced by China (7), the USA (7), and Australia (4), Malaysia, South Korea (4), these five states covering over 40% of the publication volume. The ranking is followed by England, Germany, Spain, Sweden with 3 articles each.

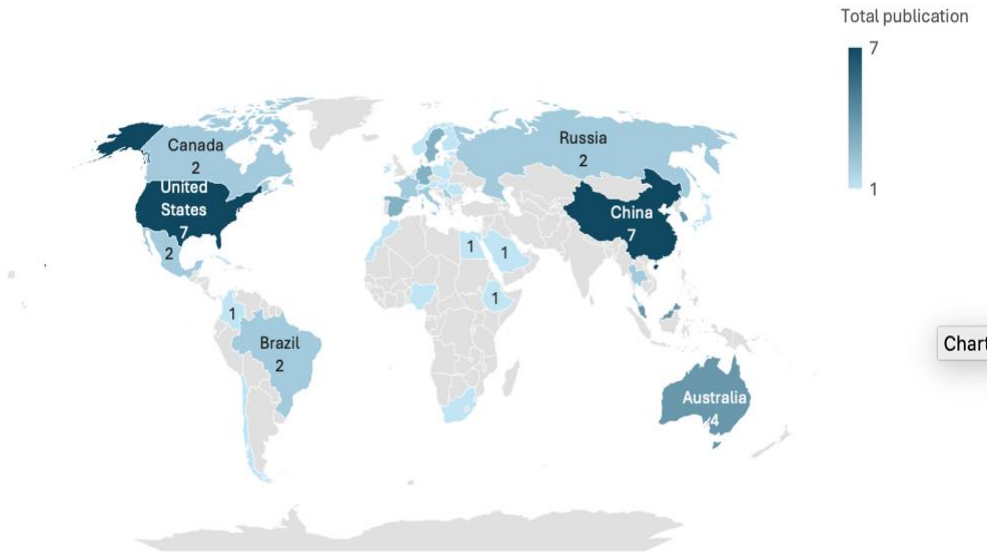

Figure 5: Prolific countries/regions
Source: Own processing, using data provided by WOS (Web of Science).

In Figure 6, obtained using VOSviewer, the most intense and close collaborations among the 9 out of 48 countries are illustrated by setting the minimum number of documents per country at 2, along with the period during which these collaborations occurred.

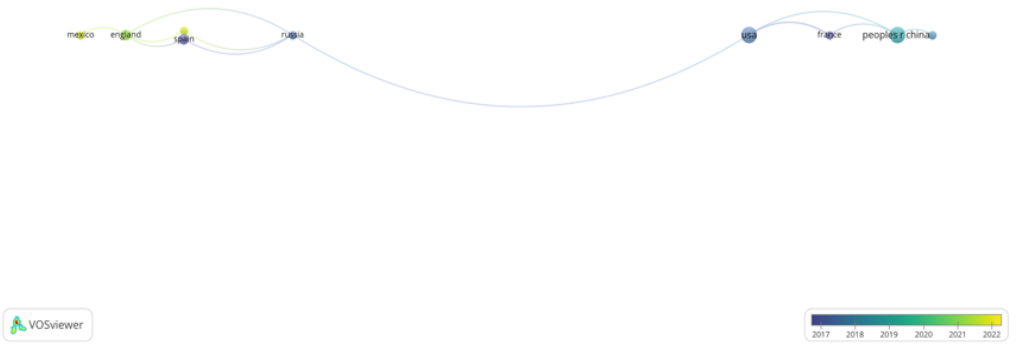

Figure 6: Country collaboration of co-authors
Source: Own processing using VOSviewer, 2023

The nodes in Figure 5 represent countries/regions, with the size of the nodes

symbolizing the number of publications, and the connecting lines between two nodes indicating a collaborative relationship between the two countries.

England has the most collaborations 4, even though it doesn't have the highest number of articles; those distinctions belong to the USA and China (each with 7 works) but only 3 collaborations. Researchers from England have collaborated with those from countries such as Spain, Russia, Brazil, and most recently, Mexico. Meanwhile, researchers from the USA have opted for collaborations with France, Russia, and the most frequent and recent collaborations being with China. In the case of China, the connections between nodes are shorter and thicker (indicating more intense and frequent collaboration), especially with those from the USA, France, and Canada.

3.5. Analysis of the most cited papers

To identify the shortcomings in the research on university-industry collaboration from the perspective of sustainable development and outline future research directions, we conducted an analysis and synthesis of the most relevant research papers on this topic. We used the same article database as in the bibliometric analysis, covering the period from 2018 to 2023. Initial searches and filters yielded 36 articles, from which we chose to present the top 10 based on the number of citations. Thus, following this selective analysis, we arrived at a total of 9 relevant articles, with one being excluded as it was not pertinent to the analyzed theme. The main conclusions of this analysis are presented in Table 2 below, with the articles arranged in descending order based on the number of citations.

Table 2: List of most cited works

No.	Authors	Publication Title	Years of Publication	Number of Citations	Journal
1	Fischer, B., Guerrero, M., Guimón, J., & Schaeffer, P. R	Knowledge transfer for frugal innovation: where do entrepreneurial universities stand?	2021	51	*Journal of Knowledge Management*
2	Van Vliet, K., Pellenq, R., Buehler, M. J., Grossman, J. C., Jennings, H., Ulm, F. J., & Yip, S	Set in stone? A perspective on the concrete sustainability challenge	2012	45	*MRS bulletin*
3	Yang Song, Jean-Michel Sahut, Zhiyuan Zhang, Yifan Tian, Lubica Hikkerova,	The effects of government subsidies on the sustainable innovation of university-industry collaboration,	2022	32	*Technological Forecasting and Social Change,*
4	Scholz, R. W.	Transdisciplinarity: science for and with society in light of the university's roles and functions.	2020	28	*Sustainability Science*

5	Zhou, C., & Etzkowitz, H.	Triple helix twins: a framework for achieving innovation and UN sustainable development goals	2021	23	*Sustainability*
6	Bjursell, C., & Engström, A.	A Lewinian approach to managing barriers to university–industry collaboration	2019	13	*Higher Education Policy*
7	Lew, Y. K., & Park, J. Y	The evolution of N-helix of the regional innovation system: Implications for sustainability.	2021	10	*Sustainable Developmen*
8	Iqbal, J., Kousar, S., & Ul Hameed, W.	Antecedents of sustainable social entrepreneurship initiatives in Pakistan and Outcomes: Collaboration between quadruple helix sectors.	2018	9	*Sustainability*
9	Castro Peixoto, L., Barbosa, R.R. & de Faria, A.F.	Management of Regional Knowledge: Knowledge Flows Among University, Industry, and Government	2022	7	*J Knowl Econ*

Source: Own processing, using data provided by WOS

The most cited paper, with a total of 51 citations, is "Knowledge transfer for frugal innovation: where do entrepreneurial universities stand?" by Fischer, B., Guerrero, M., Guimón, J., & Schaeffer, P. R. The paper analyses the strategic knowledge transfer practices implemented by an entrepreneurial university to foster frugal innovations in an emerging economy. It is based on a case study of the University of Campinas (Unicamp), incorporating 14 interviews and secondary data sources. The results highlight the internal capabilities of universities to promote frugal innovations and connect them to markets, as well as the surrounding innovation ecosystems in which the university is integrated and the overall institutional framework.

4. Conclusions

The present study provides a detailed analysis of the relationship between universities and industry from the perspective of sustainable development, utilizing a bibliometric framework to assess the relevance and researchers' interest in this field. The conclusions drawn from the conducted analysis reveal the global characteristics of specialized literature, with significant contributions originating from various regions worldwide. The United States and China have been the primary producers of publications in this domain, each with seven works, followed by Australia (4) and England (3). A notable aspect is the substantial increase in the volume of articles starting in 2019, with a focus on environmental protection funding.

The keyword-based analysis highlighted frequently used terms such as

"University-industry collaboration," "sustainability," "triple helix," "management," and "innovation." The most cited author in this field is Etzkowitz H. from the International Triple Helix Institute in the United States, and one of the most cited articles is co-authored with Zhou, C.Y. from Hohai University, proposing a Triple Helix model of university-public-government for sustainable development, complementing the university-industry-government Triple Helix for innovation.

This bibliometric analysis not only emphasizes the present but also tracks the evolution of researchers' areas of interest in the field of the university-industry relationship for sustainable development. However, it is crucial to acknowledge that results may evolve with the continuous update of the database, and the study recognizes the temporal and dynamic limitations associated with this aspect.

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