

Global Evolution of Research on Sustainable Development and Carbon Dioxide Emissions: a Bibliometric Review

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Abstract

This article aims to analyze and synthesize the research conducted over time of scientific publications in the field of sustainable development and carbon dioxide emissions (CO₂ emissions) by investigating the most relevant articles, authors, journals, countries, and organizations.

We applied a quantitative research methodology by conducting a bibliometric analysis related to sustainable development and CO₂ emissions. Using the VOS viewer program, we mapped this research field using co-occurrence keywords, highlighting the most important connections between these two concepts. This software graphically displayed the data and identified four clusters/research lines concerning sustainable development, economic growth, CO₂ emissions, and environment.

The analysis includes the most relevant 258 publications indexed in the Web of Science Core Collection database from 2000 to 2022, including 63 countries. The main findings indicate that the scientific interest in the field of sustainable development and CO₂ emissions has progressively increased in the last three years (60% of the articles).

Key words: bibliometric analysis, sustainable development, CO₂ emissions, VOS viewer

J.E.L. classifications: M14

1. Introduction

Our study examines 258 publications published between 2000 and 2022. We collected data from the Web of Science (WoS) and visualized it using the VOSviewer program tools like keyword co-occurrence or bibliographic coupling. The present analysis contributes to the literature on sustainable development and CO₂ emissions because it structures and synthesizes all the previous research in this field. Additionally, it offers helpful details regarding pertinent contributions, authors, journals, and research directions. A mapping of a scientific field is useful to researchers because having a map of a discipline's conceptual framework can be of great interest in the pursuit of a holistic view of a field of study, improving the understanding of relationships between paradigms and the most studied topics and, thus, identifying essential work still to be done.

In the next section of the article, we present a short overview of the scientific literature in the field of the topic, and then we describe the methods and data we used. The 4th section contains the results of the bibliometric analysis, and in the last section, we outline the main conclusions.

2. Literature review

The most significant problem of our time - climate changes - pose a danger to natural life, security, and prosperity (Ahmed et al., 2019). Human activity has been linked to a pronounced rise in CO₂ emissions worldwide during the past few decades

The Inter-Governmental Panel on Climate Change (IPCC) declared in 2013 that CO₂ emissions are the biggest source of global warming. The "Kyoto Protocol," which was signed by more than 100 nations in 1997, set a goal of lowering CO₂ emissions in order to protect developed economies from the harmful impacts of global warming¹. Initially, developing nations did not pay much attention to reducing CO₂ emissions, but, as a result of their fast economic development, these nations now show a major concern for doing so (Pang, 2015).

Furthermore, Yang et al. (2020) showed in the context of developing nations that an increase in economic growth is positively correlated with CO₂ emissions, which are dangerous to the environment. The theoretical underpinnings suggest that CO₂ emissions pose great risks to the prosperity of humans on this planet (Hasanov et al. 2021). Academics believe that fundamental human needs such as health, food security, and economic development could be hindered as CO₂ emissions rise. They recommend that countries around the world take action to reduce their CO₂ emissions by engaging in activities that are friendly to the environment.

Nowadays, the term CO₂ emissions widely appear in the economic literature associated with the environmental quality across the globe and ecological footprint.

Although it recently brought together a variety of disciplines and interests, including ecology as well as environmental, economic, and social elements, the idea of sustainable development has its origins in ecology. Researchers from several disciplines approach the study of sustainable development from various angles and with various emphasizes (Ramos and Caeiro, 2010).

Environmentalists and ecologists focus on healthy survival of people as well as the sustainability of ecosystems and the local environment while studying sustainable development from the perspectives of ecological environment pollution, biodiversity, and ecosystem optimization (Liu, Brown et al, 2017).

Economists also employ economic theories and methods to explore ways to activate economic power to promote sustainable development. Researchers like Rais et al. and Zhang et al. approached their study from this angle.

Sociologists emphasize the value of creating a structural system that incorporates the market, policy, moral standards, science, and technology, as well as other elements, in order to maximize the cohesion of nature, humanity, and society on the path to sustainable development.

Although there are several definitions of sustainable development, the fundamental goal remains the same: integrating economic, social, and environmental progress while maximizing the welfare of all future generations.

3. Research methodology

The purpose of this research is to carry out a bibliometric mapping of the research conducted over time in scientific papers on sustainable development and CO₂ emissions by using data extracted from the WoS platform. We chose the WoS Core Collection because is an internationally renowned source that respects the highest standards and provides more than 15,000 of the most important and relevant journals and more than 50,000,000 classified documents.

The methodology involves identifying, organizing, and analyzing the interrelation between sustainable development and CO₂ emissions by searching the most frequently used terms in this specific research field.

We chose a bibliometric analysis because it is a set of methods used to study or measure information, especially in big datasets like WOS, and it is a quantitative research assessment of academic output. A bibliometric analysis contains two main procedures: a performance analysis and a science mapping (Cobo et al. 2011).

The science mapping displays the structural and dynamic aspects of science by representing the cognitive structure of research. Regarding the science mapping, our study examined the architecture of connections and various components of analysis, clustering for the analyzed fields, the relevance of the key issues revealed, and their relationships in multiple settings (clusters).

According to Cobo, the most essential steps in conducting a bibliometric analysis are the following:” data retrieval, preprocessing, network extraction, normalization, mapping, analysis, and visualization” (Cobo et al., 2011).

Figure no. 1 Diagram of the methodology used



Source: (Cobo et al., 2011)

In order to carry out the bibliometric analysis of sustainable development and CO2 emissions, we ran an advanced search on the keywords: "SUSTAINABLE DEVELOPMENT" AND "CARBON DIOXIDE EMISSIONS" in the Topic. The search in WOS was performed on 1 20 October with no time limit. and covers 2646 papers.

The publications were filtered by research area criteria (economics, management, business, business-finance), resulting only 285 publications. Then, we applied the filter of document types (excluding the other forms of publications: proceedings papers, early access, book chapters, review articles, and editorial materials), so the final result was 258 articles of the most important publications that make up our sample. The procedure for choosing samples is shown in the following diagram.

Figure no. 2 Diagram of the Wos CC research



Source: own generation

We used the VOS viewer application to generate science mapping by visualizing the networks between sustainable development and Co2 emissions in order to build a quantitative analysis of the relevance of these two concepts in the existing research. Through several linkages, such as co-authorship, co-occurrence, citation, bibliographic coupling, and co-citation, VOS viewer may display the structure and networks of various types of things, including authors, references, keywords, journals, organizations, and nations.

4. Findings

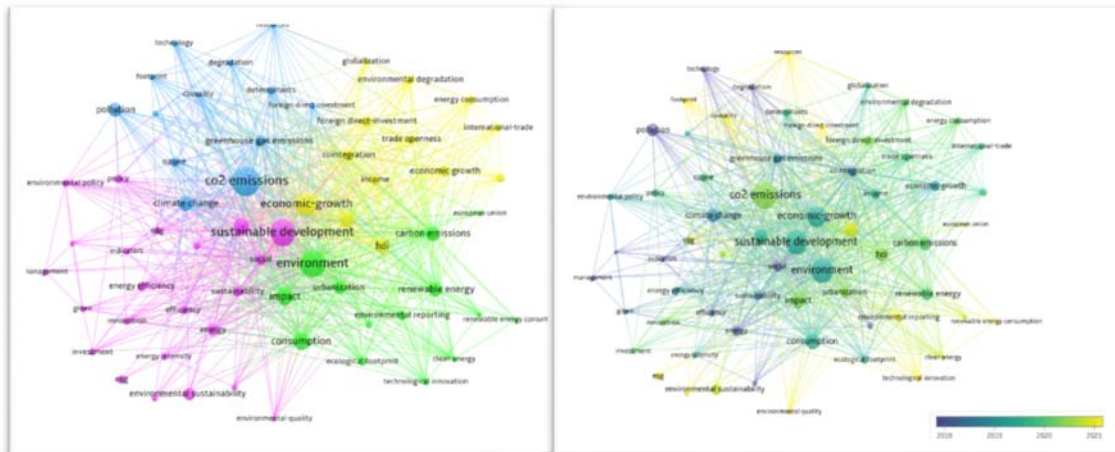
In order to generate a science mapping, the 258 articles regarding sustainable development and CO2 emissions were exported into a plain text format (txt), including full records and cited references, in the VOS viewer software for further analysis, to identify the existing correlations.

We conducted many analyses to collect the most important data on the researched subject. We present data on the number of publications to provide a broad overview of the sustainable development and CO2 emissions. Second, we concentrate on the top journals, authors, and universities. The subsequent subsections analyze the various VOSviewer maps, starting with a keyword co-occurrence analysis, moving on to a bibliographic coupling of references and authors, and concluding with a co-authorship study of organizations and countries.

Using co-occurrence analysis, from the 258 publications, the algorithm retrieved 111 keywords with at least five occurrences, from which the program only chose the 60% of terms (65) that were highly relevant to our research and included them in the final analysis. Using the Thesaurus function, common words like article, author, data, model, paper, study, theory, value, and year or synonyms were dropped from the list because.

Colored circles served as labels for the 65 keywords. The number of times a term appears in the titles and abstracts is associated with the size of the letters and circles. The letters and circles get bigger the more frequently a keyword appears ².

Figure no. 3 VOSviewer co-occurrence map – association strength and overlay display

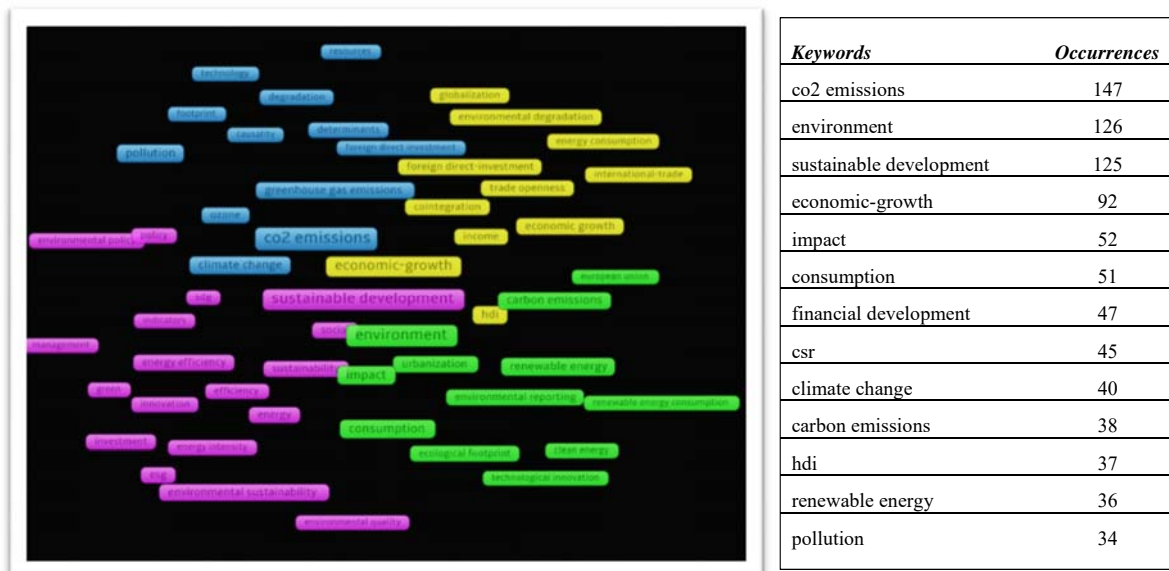


Source: own generation using data from WOS database

The co-occurrence network is grouped into 4 clusters (fig. no. 3) by their relevance, every cluster might be thought of as a topic: sustainable development, economic growth, CO2 emissions, and environment. The overlay display identifies the significant research fields for the long-term future by illustrating the main trends in recent years: ESG, technological innovation, and environmental sustainability.

The **purple cluster** – sustainable development - compresses 23 terms, the most significant cluster with 1.798 link strength and 414 occurrences. The most relevant keywords are: CSR, ESG, SDG, green, and sustainability. The **green cluster** – environment- represents 14 terms, having the biggest link strength - 2.744 units and 407 co-occurrences. The main keywords in this cluster refer to environmental reporting, clean energy, ecological footprint, and renewable energy. The **blue cluster** – CO2 emissions- contains 13 keywords, 318 co-occurrences, and 1.108 link strength, and it refers to climate change, greenhouse gas emissions, pollution, and resources. The **yellow cluster** – economic growth - consists of 13 terms, with 341 co-occurrences and 2.234 link strength.

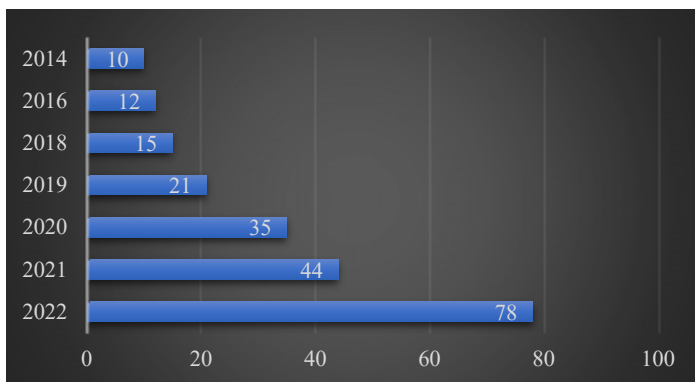
Figure no. 4 Summary of the most important keywords in clusters



Source: own generation using VOS viewer

The years with the most published articles are 2022 -78, 2021 – 44, and 2020 with 35 publications. We can notice a rise in the scientific interest in CO2 emissions and sustainable development, as evidenced by the increasing number of published studies over the last three years.

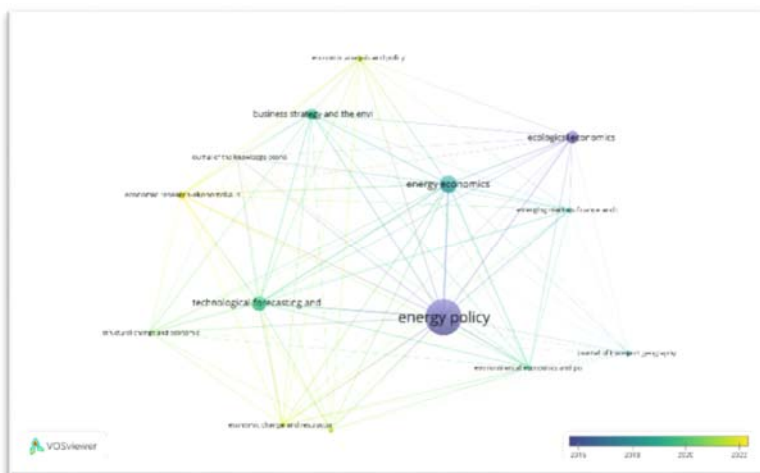
Figure no. 5 Analysis using publication years criteria



Source: own generation using data from WOS database

The next type of visualization provides a quick overview of the most important journals. We can visualize that the total link strength indicates that the most productive journals are Energy Policy, with 45 articles published, followed by Technological Forecasting and Social Change, with 20, and Energy Economics, with 17.

Figure no. 6 VOSviewer bibliometric coupling journals

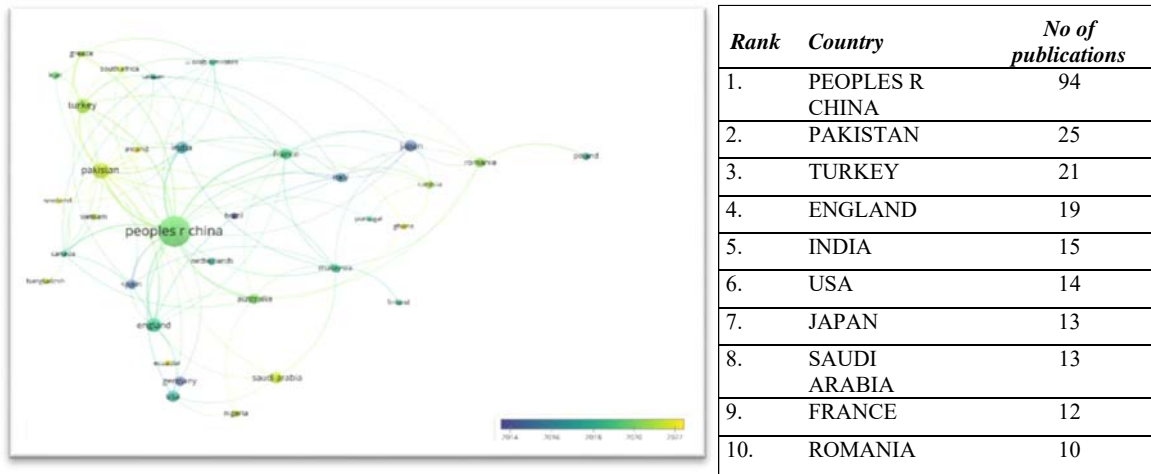


Source: own generation using VOS viewer

Then, we analyzed the country criteria, and we remark that the authors writing in the field of sustainable development and CO2 emissions mostly belong to the People of China (94), Pakistan (25), and Turkey (21).

The next diagram presents the co-authorship analysis and displays the collaboration networks between different countries. The node’s size indicates the importance of that item (in this case, the number of publications), while the distance reflects the degree of collaboration. According to the total link strength, the People of China is far away the country that collaborates the most with other countries when publishing about sustainable development and CO2 emissions.

Figure no. 7 Co-authorship network of countries

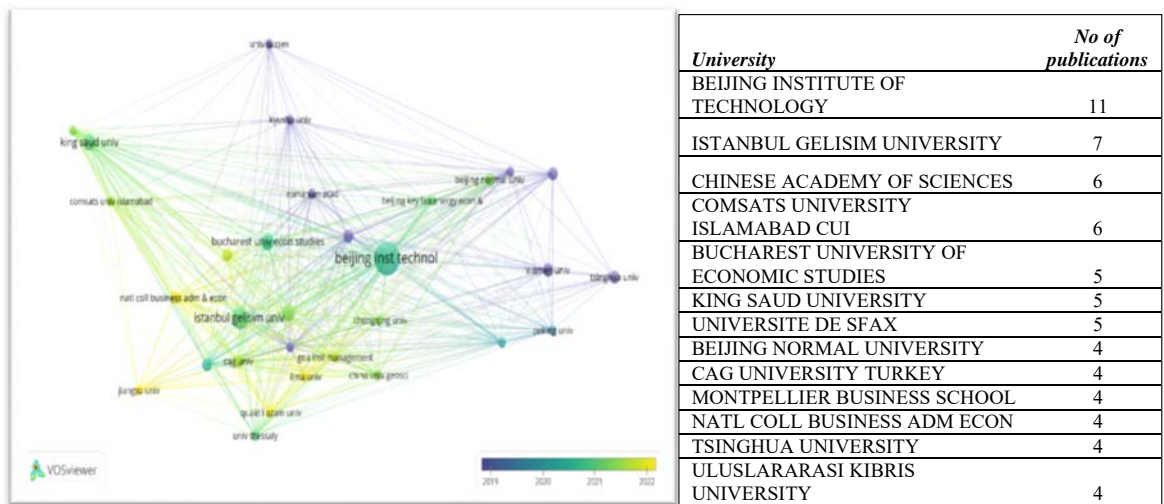


Source: own generation using VOS viewer

Regarding the co-authorship analysis of organizations, we find that the most productive institutions by number of published documents are Beijing Institute of Technology with 11, Istanbul Gelisim University with 7, and with 6 publications, both Chinese Academy of Science and Comsats University Islamabad Cui. However, the total link strength indicates that the ones that collaborate most with other organizations are King Saud University and Istanbul Gelisim University.

Regarding the overlay map of the co-authorship network of universities, we can notice that there is a new current belonging to research about sustainable development and CO2 emissions at Ilma University, National College of Business Administration and Economics, and Quaid I Azam University.

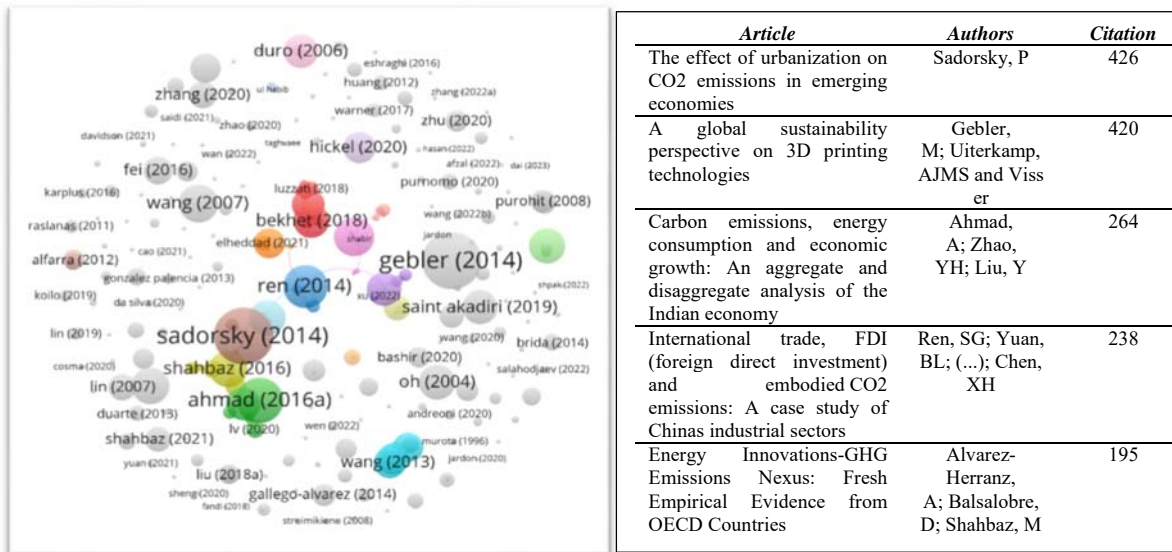
Figure no. 8 Co-authorship network of universities



Source: own generation using VOS viewer

The following figure represents the bibliographic coupling where we can analyze groups of authors and their research interests. This analysis is also helpful in identifying relevant authors that might specialize in one of the streams of research. The most cited authors are Sadorsky, Gebler, and Ahmad. Also, the most productive authors writing about sustainable development and CO2 emissions are Hao and Shahbaz, with 5 publications.

Figure no. 9 Bibliographic coupling of authors



Source: own generation using VOS viewer

5. Conclusions

The goal of this article was to analyze the evolution of research articles on sustainable development and CO2 emissions on a worldwide scale. The study examined 258 publications from 63 countries between 2000 and 2022. This article has mapped the literature in sustainable development and CO2 emissions using bibliometric methodologies.

The exponential increase in the number of articles published suggests the topic's relevance. The years with the most published papers are 2022 -78, 2021 – 44, and 2020 with 35 publications. We can notice that there is a rise in scientific interest in the field of CO2 emissions and sustainable development, 60% of the articles was published over the last three years. With an average of 29.38 citations per item, the number of citations also reflects the topic's importance.

The most cited articles were written by Sadorsky and Gebler et. al with 426 and 420 citations. Additionally, Also, Hao and Shahbaz have contributed to the research with the most publications - 5 articles.

Energy Policy, with 45 articles published, followed by Technological Forecasting and Social Change with 20, and Energy Economics with 17, are the most productive journals in this discipline by the number of articles published.

The analyses focusing on keyword co-occurrence emphasize a total of four research lines in the literature: sustainable development, economic growth, CO2 emissions, and environment.

Regarding the country criteria, we find that People of China is far away the country that has published the most about sustainable development and CO2 emissions, followed by Pakistan (25) and Turkey (21). We remarked that almost 40% of the publications belong to the People of China (94).

The next diagram presents the co-authorship analysis and displays the collaboration networks between different countries. The node's size indicates the importance of that item (in this case, the number of publications), while the distance reflects the degree of collaboration. According to the total link strength,

In what concerns the co-authorship analysis of organizations, we find that the most productive institutions by the number of published documents are Beijing Institute of Technology with 11, Istanbul Gelisim University with 7, and with 6 publications, both Chinese Academy of Science and Comsats University Islamabad Cui. Also, the overlay analyses showed a new current belonging to research about sustainable development and CO2 emissions at Ilma University, National College of Business Administration and Economics, and Quaid I Azam University.

Overall, the research's analysis reveals an exponential rise in the scientific community's interest in sustainable development and CO2 emissions, as seen by the consistent growth of publications, authors, and citations.

This study was only linked to a selected bibliography from the WOS platform, additional databases, such as Scopus or Google Academic, were omitted. This last point represents a limitation of the research. Similarly, the analysis has only considered the articles, disregarding other factors such as proceedings papers, early access, book chapters, review articles, and editorial materials.

6. References

- Ahmed, N., Thompson, S. & Glaser, M., 2019. Global Aquaculture Productivity, Environmental Sustainability, and Climate Change Adaptability. *Environmental Management* 63, 159-172. <https://doi.org/10.1007/s00267-018-1117-3>
- Cobo, M.J., López-Herrera, A.G., Herrera-Viedma, E., Herrera, F., 2011. Science mapping software tools: Review, analysis, and cooperative study among tools. *Journal of the Association for Information Science and Technology*, Vol. 62, No.7, pp. 1382-1402. <https://doi.org/10.1002/asi.21525>
- Donthua, N., Kumar, S. and Pattnaik, D., 2020. Forty-five years of Journal of Business Research: A bibliometric analysis. *Journal of Business Research*, Vol. 109, No. 1, pp. 1-14. <https://doi.org/10.1016/j.jbusres.2019.10.039>
- Donthua, N., Kumarbe, S., Mukherjee, D., Pandey, N. and Limde, E.M., 2021. How to conduct a bibliometric analysis: An overview and guidelines. *Journal of Business Research*, Vol. 133, pp 285-296. <https://doi.org/10.1016/j.jbusres.2021.04.070>
- Fusco, F. and Ricci, P., 2019. What is the stock of the situation? A bibliometric analysis on social and environmental accounting research in the public sector. *International Journal of Public Sector Management*, Vol. 32 No. 1, pp. 21-41. <https://doi.org/10.1108/IJPSM-05-2017-0134>
- Haque, F. and Ntim, C. G., 2017. Environmental Policy, Sustainable Development, Governance Mechanisms, and Environmental Performance. *Business Strategy and the Environment*, Vol. 27, No. 3, pp. 415-435. <https://doi.org/10.1002/bse.2007>
- Hasanov FJ, Khan Z, Hussain M, Tufail M., 2021. Theoretical Framework for the Carbon Emissions Effects of Technological Progress and Renewable Energy Consumption. *Sustainability Development* 29(5):810-822. <https://doi.org/10.1002/sd.2175>
- Ivan, O. R., (Câmpean) Pătrînjan, I.B., 2021. The importance of non-financial reporting research-a bibliometric analysis. *The USV Annals of Economics and Public Administration*, Vol. 21, No. 2, pp. 121-130.
- Javaid A, Arshed N, Munir M, et al. 2022. Econometric Assessment of Institutional Quality in Mitigating Global Climate-Change Risk. *Sustainability*, 14(2):1-13. <https://doi.org/10.3390/su14020669>
- Liu, G.; Brown, M.T.; Casazza, M. 2017. Enhancing the sustainability narrative through a deeper understanding of sustainable development indicators. *Sustainability*, 9, 1078. <https://doi.org/10.3390/su9061078>
- Mohammed A, Li Z, Olushola Arowolo A, et al. 2019. Driving factors of CO2 emissions and nexus with economic growth, development and human health in the Top Ten emitting countries. *Resour Conserv Recycl*, 148(March):157-169. <https://doi.org/10.1016/j.resconrec.2019.03.048>
- Nan Ye, Tung-Boon Kueh, Lisong Hou, Yongxin Liu, Hang Yu., 2020. A bibliometric analysis of corporate social responsibility in sustainable development. *Journal of Cleaner Production*, Vol. 272. <https://doi.org/10.1016/j.jclepro.2020.122679>
- Pang, L. 2015. Openness to Trade, Urbanization and carbon emission based on model ARDL in Jiangsu. *China Population. Resources and Environment*, 25, 430–434.
- Rais, M. Craswell, E. Dumanski, J. 1998. Resource management domains as a vehicle for sustainable development. *Cognizant Communication Corporation*, Vol. 2, No 1, pp. 3-7. <https://doi.org/10.3727/108812898792195561>
- Ramos, T.B.; Caeiro, S. 2010. Meta-performance evaluation of sustainability indicators. *Ecological Indicators* 2, 157-166. <https://doi.org/10.1016/j.ecolind.2009.04.008>
- Svensson, G., Ferro, C., Høgevold, N., Padin, C., Carlos Sosa Varela, J., Sarstedt, M., 2018. Framing the triple bottom line approach: Direct and mediation effects between economic, social, and environmental elements. *Journal of Cleaner Production*, Vol. 197, pp 972-991. <https://doi.org/10.1016/j.jclepro.2018.06.226>

- *The World Business Council for Sustainable Development*: available at <https://www.wbcsd.org/> accessed on 26 October 2022.
- van Eck, N. J. and Waltman, L., 2010. Software survey: VOSviewer, a computer program for bibliometric mapping. *Scientometrics*, Vol. 84, No. 2, pp. 523-538. <https://doi.org/10.1007/s11192-009-0146-3>
- van Eck, N. J. and Waltman, L., 2017. Software survey: Citation-based clustering of publications using CitNetExplorer and VOSviewer. *Scientometrics*, Vol. 111, No 2, pp. 1053-1070. <https://doi.org/10.1007/s11192-017-2300-7>
- van Eck, N. J., & Waltman, L. 2013. *{VOSviewer} manual*. Leiden: Univeriteit Leiden, January. http://www.vosviewer.com/documentation/Manual_VOSviewer_1.6.1.pdf accessed on 04 November 2022.
- van Eck, N. J., and Waltman, L., 2011. Text mining and visualization using VOSviewer. *ISSI Newsletter*, Vol. 7, No. 3, pp. 5.
- *VOSviewer software tool*, downloaded from: <https://www.vosviewer.com/>, downloaded on 26 October 2022.
- Web of Science Core Collection: *Web of Science: Summary of Coverage* available at: <https://clarivate.libguides.com/woscc/coverage>, accessed on 20 October 2022.
- Yang, B., Ali, M., Nazir, M. R., Ullah, W., & Qayyum, M. 2020. Financial instability and CO 2 emissions: cross-country evidence. *Air Quality, Atmosphere and Health*, 13, 459-468. <https://doi.org/10.1007/s11869-020-00809-7>
- Zhang, Y.L.; Qin, F.; Wu, Y. 2015. Sustainable Growth or Growth with Pollution: An Analysis on the Sales Growth Patterns of Chinese Industrial Companies. *China Ind. Econ*, 2, 89–101.