International Journal of Energy Economics and Policy

ISSN: 2146-4553

available at http: www.econjournals.com

International Journal of Energy Economics and Policy, 2024, 14(3), 549-559.

Shaping the Future of Environmental Economics: A Bibliometric Review of Current Trends and Future Directions

Muhamad Subhi Apriantoro[1]*, Rizki Dwi Putra Rosadi[1], Arminda Cahya Ramdhani[1], Ninik Andriyani[2]

[1]Universitas Muhammadiyah Surakarta, Indonesia, [2]Universitas Sebelas Maret, Indonesia. *Email: msa617@ums.ac.id

Received: 23 November 2023 **Accepted:** 01 April 2024 **DOI:** https://doi.org/10.32479/ijeep.15502

ABSTRACT

Environmental economics is increasingly pivotal in addressing global environmental challenges. This study aims to elucidate the research landscape in this field, focusing on prevalent themes such as climate change, carbon emissions, sustainable development, and environmental policy. Employing a bibliometric analysis, we analyzed a substantial corpus of literature from Scopus. We applied Lotka's Law to assess author productivity and distribution and conducted institutional and country-level analyses to map the geographical spread and institutional affiliations in environmental economics research. Our analysis highlights a significant growth in the environmental economics literature, with a notable focus on climate change and sustainability. A concentration of publications among a few authors was observed, indicating influential researchers and potential for increased collaboration. The rise in publications, particularly in China and leading journals like "The Journal of Cleaner Production," reflects a global upsurge in environmental economics research. Distinct clusters were identified, covering diverse topics from climate change economics to environmental policy. The study acknowledges limitations due to exclusive reliance on Scopus data, suggesting future research to include other databases like the Web of Science for a more comprehensive analysis. Considering the evolving nature of environmental challenges, we advocate for interdisciplinary approaches and continual updates in research to address emergent trends in this critical field.

Keywords: Sustainable Development, Climate Change Economics, Carbon Emissions Research, Environmental Policy Analysis, Eco-Economics
JEL Classifications: Q5, Q54, Q56, C8

1. INTRODUCTION

Environmental economics is a multidisciplinary field that examines the connections between the economy and the environment (Wongrak et al., 2021). It aims to assess and appraise the expenses and advantages of different environmental policies and interventions. Recently, there has been an increasing curiosity in studying environmental economics because governments, organizations, and individuals have realized the significance of sustainable development and reducing the adverse effects of economic activities on nature (Khoirunisa et al., 2023).

The issue of environmental economics has gained significant importance in alignment with the objectives of the Sustainable Development Goals (Jung and Song, 2023; Ramstetter et al., 2023). The importance of economic activities in influencing the environment and advancing sustainable development is now widely acknowledged. There is a growing recognition among governments, organizations, and individuals about the importance of assessing the expenses and advantages of environmental policies and interventions in order to fulfill their dedication to attaining Sustainable Development Goals (SDGs) (Nyeko et al., 2022). With the growing interest in environmental economics, it is crucial to understand the current research landscape in this field.

Bibliometric analysis provides a comprehensive and systematic approach to examining environmental economic studies' research trends, patterns, and impact (Zhang et al., 2023). By analyzing the bibliographic data, researchers can gain valuable insights into the current state of environmental economic research. Bibliometric

analysis is becoming increasingly popular in information science, allowing researchers to gather data on publications, citations, and collaborations within a specific field (Apriantoro et al., 2023).

Environmental economics researchers can employ bibliometric analysis tools to extract valuable insights regarding publication trends, highly cited articles, influential authors, and collaborative networks. This extensive dataset allows for deep comprehension of the present research environment. It aids in identifying areas where knowledge is lacking emerging topics of interest, and potential future paths for the field. This paper will utilize bibliometric analysis to investigate the research landscape of environmental and economic studies on the Scopus database.

One of the primary reasons for using Scopus for bibliometric analysis is its extensive coverage of scientific literature (Cabanillas-Lazo et al., 2022). Scopus includes many journals, conference proceedings, and other scholarly publications from various disciplines, including environmental economics. The comprehensive coverage of Scopus makes it an ideal tool for conducting bibliometric analysis in environmental economics (Ziabina et al., 2021). Researchers can access a vast array of research articles, allowing them to capture the breadth and depth of the field. By examining publication trends, researchers can gain insights into the growth and evolution of environmental economic research over time. They can identify key topics and themes that have received significant attention and explore how these areas have developed and expanded.

This research is anticipated to yield substantial advantages for diverse stakeholders. Policymakers can utilize the findings of this research to allocate resources and provide assistance to the most crucial and influential research domains. Enhanced comprehension of the existing research terrain will prove advantageous to researchers, aiding in identifying research deficiencies and establishing collaborative alliances. Moreover, this analysis can guide educational and research institutions in developing curricula and research initiatives that align with current trends and requirements.

This research endeavors to utilize a data-driven and comprehensive methodology to generate novel insights and establish a definitive path for advancing environmental and economic research in environmental economics. This region is crucial for the promotion of sustainable development and the advancement of global prosperity.

2. LITERATURE REVIEW

During environmental economics research, Petrovic (2022) offers an exciting view of how environmental economics and ecology are related to and influence each other. Meanwhile, Maris (2022) focuses on the dynamics between the natural environment and the human economy. Moving to a more specific realm, Larnaudie et al. (2022) explores the production of biofuels from lignocellulosic biomass, a topic of increasing importance in the era of renewable energy. Eaton et al. (2023) raise the topic of health by examining the impact of the urban environment, while Degirmencioglu Aydin and Aydin (2023) highlights the importance of supporting green growth in the economy. Majdawati and Annisa (2022) explores the use of CCHP systems in university buildings, and Zemo and Termansen (2022) explores how environmental identity influences conservation choices. Lastly, Gaur et al. (2022) highlight the challenges of increasing waste and its management.

Moving on to sustainable development and resource management, Cudjoe (2023) reviews municipal solid waste processing technology, a critical issue in sustainable urban development. In India, Praveenkumar et al. (2022) explored the potential for utilizing solar radiation, while Khan et al. (2022) focused on increasing renewable energy use in Pakistan. Thoy and Go (2022) bring a unique perspective by studying the integration of photovoltaic elements in architecture. Zhu et al. (2022) used a fuzzy AHP approach to analyze sustainability, and Ryter et al. (2022) discussed the environmental impacts of material production.

Rehman et al. (2023) investigate how electric vehicles can be integrated into energy systems in the context of technology integration and its environmental impact. Aboagye et al. (2022) examined trends in solvent use in the chemical industry, while Tariq et al. (2022) developed a holistic management approach for renewable energy. Lastly, Safiullin et al. (2016) examine how contemporary economics intersects with renewable energy distribution.

Previous research has yet to employ bibliometric methods. None of the entries in the dataset mention or provide any evidence for the utilization of bibliometric methods. Indicatively, the dataset we offer emphasizes other facets of environmental economics rather than bibliometric analyses of the field.

3. METHODOLOGY

This study adopted a bibliometric analysis approach to explore the domain, employing a multi-phased methodology (Apriantoro et al., 2023). The process commenced with brainstorming to determine relevant keywords, setting the stage for a targeted literature search. We then conducted a systematic search in the Scopus database, using a combination of keywords "environmental AND economics" and applying specific filters: A time range from 2014 to 2023, articles within the subject area of Economics, Econometrics, and Finance, and English languages journals (Apriantoro et al., 2023). This search yielded 5 332 documents. Subsequent analysis was conducted using R Studio and Python, focusing on comprehensively examining the documents to discern prevalent themes and trends.

Additionally, network analysis via VOSviewer, specifically co-occurrence analysis, was employed to uncover the interconnectivity and thematic clusters within the literature. The culmination of this methodical approach was the identification of key research directions in environmental economics, providing a nuanced understanding of the field's current landscape and potential future developments. The flow of this method can be seen in Figure 1.

4. RESULTS AND DISCUSSION

Table 1 provides a clear and concise summary of the descriptive statistics for each temporal grouping: Early, Mid, and Late periods.

The data is classified into three temporal groups: Early, Mid, and Late, representing equal divisions of the total time range. The count column displays the number of data points in each period, with 4 in the Early period, 3 in the Mid period, and 3 in the Late period. The mean column presents the average count for each period, specifically 379.75 for Early, 532.33 for Mid, and 728.67 for Late, indicating a progressive trend. The standard deviation quantifies the dispersion of values around the mean. Specifically, the values for Early, Mid (with the lowest variability), and Late (with the highest variability) are 62.61, 8.08, and 149.95, respectively. The minimum count recorded in each period is 335 for Early, 523 for Mid, and 628 for Late. The 25th percentile is the value below which 25% of the data falls. Specifically, for the Early category, the value is 338.75; for the Mid category, it is 530; and for the Late category, it is 642.50. The median is the central value in a set of ordered data, with 357 representing the Early category, 537 representing the Mid category, and 657 representing the Late category. The 75th percentile represents the value below which 75% of the data falls. Specifically, for the Early category, the 75th percentile is 398; for the Mid category, it is 537; and for the Late category, it is 779. The highest number recorded during each period is 470 for Early, 537 for Mid, and 901 for Late. The variance, a measure of the squared dispersion, is 3920.25 for the Early group, 65.33 for

Figure 1: Data processing flow

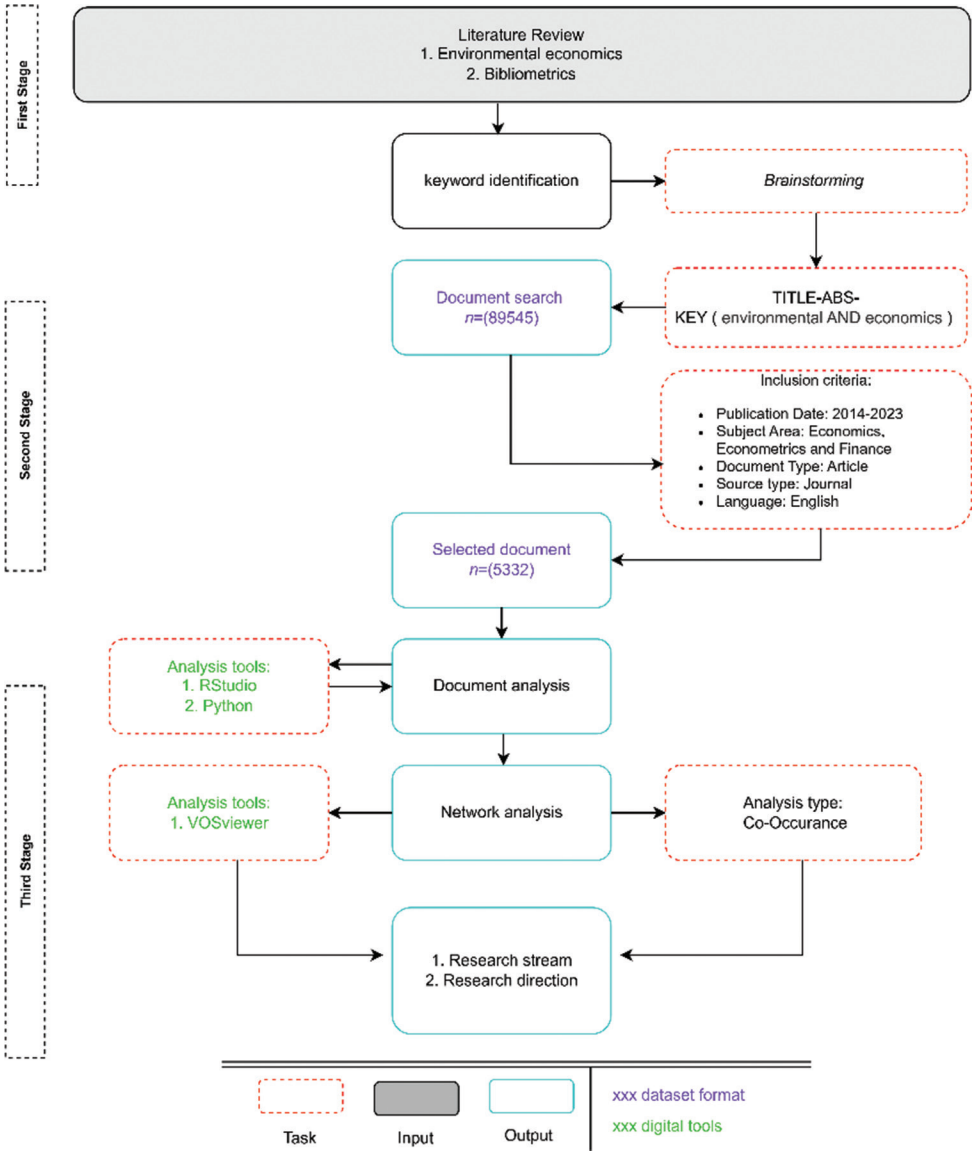


Table 1: Summary of the descriptive statistics

Period	Count	Mean	Standard deviation	Minimum	25th %	Median	75th %	Maximum	Variance
Early	4	379.75	62.61	335	338.75	357	398	470	3920.25
Mid	3	532.33	8.08	523	530	537	537	537	65.33
Late	3	728.67	149.95	628	642.5	657	779	901	22484.33

the Mid group (indicating similar counts), and 22484.33 for the Late group (indicating a higher level of dispersion).

These statistics indicate that the counts have increased over time, as evidenced by the rising mean and median from the early to the late period. The late period also shows a significantly higher variance, indicating a more extensive data spread.

The count data in Figure 2 shows a clear increasing trend from the early to late periods, indicating growth or an increase in the metric being measured over time. The mean values for each period support this trend, with the early period having the lowest average count of around 349.67. This suggests that the metric started at a lower baseline during the early years. In the mid-period, there was a steady rise in the mean count to approximately 514.67, indicating an increased activity or interest in the subject area. The late period saw a sharp increase in the mean count to about 677.25, indicating a significant jump from the mid-period.

Increased awareness, funding, or research activity could influence this rapid change. The mid-period appears to be more stable, with counts remaining within a similar range, while the late period shows a steeper increase, suggesting a more rapid change during those years. The increasing trend in the count and mean values may have different implications depending on the context of the data, such as research field or environmental incidents, and may require further investigation.

Figure 3 shows the most popular authors. Hanley, N is the most famous author with 22 publications. The range of publications among these authors is from 11 to 22, which suggests a relatively even distribution of productivity at the higher end of the spectrum. There is no extreme outlier, as all authors are within a band of 11 publications.

With many highly productive authors, there may be a higher potential for collaboration. Researchers with similar publication counts might be at similar career stages or have similar work habits, making them compatible with collaborative work.

Lotka's Law, in bibliometrics, is a statistical distribution used to describe the frequency of publications by authors in a given field. It predicts that the number of authors making n contributions is about $1/n^2$ of those making one contribution (Zhu et al., 2022).

In the scatter plot, each blue point represents the number of authors (on the y-axis) who have written a specific number of documents (on the x-axis). The red line shows the theoretical distribution according to Lotka's Law, where the number of authors making n contributions equals $1/n^2$ of those making one contribution. This line was fitted using an approximation from the first data point.

Figure 4 illustrates the author's contribution as determined by Lotka's Law. By examining the plot, we can see the strong correlation between the data and the predictions made by Lotka's Law. This type of analysis is beneficial in bibliometrics as it allows for a comprehensive understanding of the productivity patterns exhibited by authors within a particular field or dataset.

Figure 2: Trend of count over the years

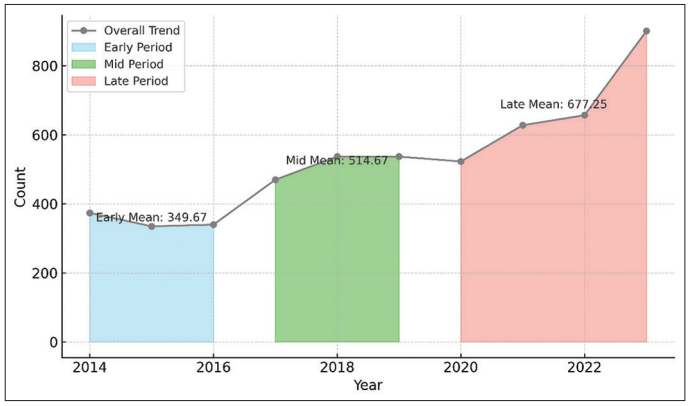


Figure 3: Most popular author

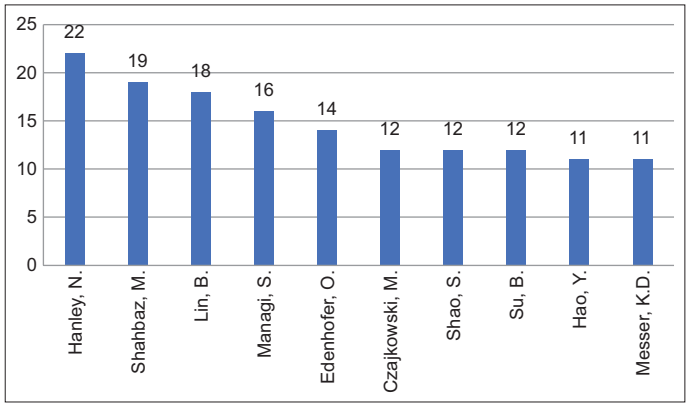
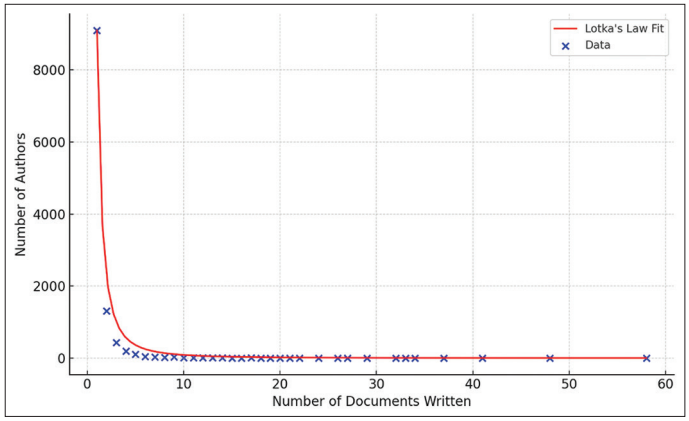


Figure 4: The author's contribution is based on mapping Lotka's Law



By applying Lotka's Law, data analysis provides valuable insights into the productivity of authors in academic publications. The analysis uncovers a prevalent trend: Numerous authors have produced only a limited number of papers, whereas a minor group has authored a substantial amount. The scatter plot demonstrates a noticeable pattern, as the distribution of authors' productivity somewhat corresponds to Lotka's Law, which is graphically represented by a red curve. Nevertheless, variations are significant, particularly among individuals with more published works. These deviations, although anticipated, emphasize the disparity between theoretical models and real-world data, which is influenced by specific trends in academic disciplines, data collection timeframes, and research methodologies.

The distribution curves also provide insight into the dynamics within particular research domains. Steep curves indicate a higher degree of concentration of publications among a smaller number of authors, whereas a gentler slope indicates a broader distribution of authorship. This information is vital for research institutions and funding bodies, as it assists in policy-making and the allocation of resources. Understanding that a small proportion of authors make the majority of contributions can help guide decisions regarding the allocation of grants, support for research, and acknowledgment in academia.

Nevertheless, it is crucial to acknowledge that Lotka's Law is a reduction. The distribution of author productivity is influenced by factors such as collaboration patterns, multidisciplinary research, and variations specific to different fields. Hence, the analysis offers a broad yet incomplete comprehension of academic authorship patterns.

Notably, there are notable differences when comparing the number of publications by the top 10 authors with the expected counts based on Lotka's Law. The authors with the highest productivity significantly surpass the expected counts, suggesting that these individuals are exceptional outliers in terms of their productivity. This disparity implies that variables such as influence, resources, and connections, which are not considered in Lotka's Law, have a substantial influence on facilitating higher publication rates. Moreover, the significantly lower predicted numbers suggest the scarcity of high publication counts according to Lotka's Law, which is in contrast to more prolific academic authors. This analysis highlights the intricate and varied behaviors of research authorship and the shortcomings of theoretical models in accurately representing real-world dynamics.

To summarise, Lotka's Law accurately describes the overall distribution of author productivity but fails to consider the exceptional productivity levels achieved by the most successful authors. These highly accomplished authors greatly surpass the productivity levels anticipated by the model, suggesting that other factors play a role in determining the publication rates of the most productive authors.

The heatmap illustrates the temporal patterns of article publications across various affiliations. The heatmap uses darker colors to represent more articles, as demonstrated by the color bar on the right side. An important observation derived from the heatmap is the consistent upward trend in the number of publications over the years for most affiliations. Furthermore, certain associations experience substantial expansion during specific years, as indicated by darker hues in their corresponding columns. This indicates that these associations witnessed a significant surge in published articles during those years. The heatmap offers a concise overview of article publications' spatial and temporal patterns based on affiliation.

The heatmap visualization in Figure 5 offers significant insights into the temporal publication output of various affiliations. First and foremost, every affiliation exhibits a rising publication trend, indicating a growing focus on research output. Furthermore, affiliations have diversity, with certain ones gradually rising while others undergo rapid expansion. Tsinghua University has experienced substantial expansion since 2016. Furthermore, there are occurrences of data sparsity, wherein particular affiliations have no documented publications for particular years.

Conversely, certain years exhibit significant increases in publications for specific affiliations, suggesting potential institutional tactics or partnerships. Later, institutions like Tsinghua University and the University of International Business and Economics emerged as prominent and influential entities. Nevertheless, it is crucial to acknowledge possible data discrepancies, such as sudden shifts in color and external influences that affect the frequency of publications. In summary, the heatmap provides valuable information about trends in research publications, helping to establish benchmarks and better understand the research productivity landscape.

Figure 6 displays the increase in publications categorized by country. The line plot offers valuable insights into the temporal evolution of research output across various countries. Initially, there is a general expansion in the quantity of articles generated by all nations between 2014 and 2023, suggesting a rise in research productivity. China is particularly noteworthy for its rapid and substantial growth in research output, especially since 2018. Conversely, countries such as the USA, United Kingdom, Germany, and France exhibit consistent expansion, albeit slower than China. By analyzing the trajectories, we can deduce the rate of research advancement in each country. China has exhibited more rapid growth in its research endeavors than the other countries in this dataset. This data emphasizes the changing nature of research output and the significant expansion of China's research productivity.

China stands out prominently in terms of the total number of citations, reaching a remarkable count of 31,773. This suggests that substantial research output garnered widespread recognition and citation. Such a high citation count indicates a robust global impact and likely signifies the presence of a large and active research community in China. The United States is the second most cited country, albeit with less than half of China's total citations. This indicates a solid contribution to the global research landscape, albeit on a comparatively smaller scale.

On the other hand, other countries listed in the dataset exhibit significantly fewer total citations. This could be attributed to smaller research communities, lower research output, or a more significant focus that may result in fewer overall citations. The total citations of the top 10 countries are shown in Table 2 below.

There is no direct correlation between the total number of citations and the average number of citations per article. For example, China, while having the highest total citations, does not have the highest average, suggesting a very high volume of publications with a moderate average citation rate. Conversely, Sweden has a lower total number of citations but the highest average citations per article, indicating fewer but highly impactful publications.

Figure 5: The heatmap visualization affiliation over time

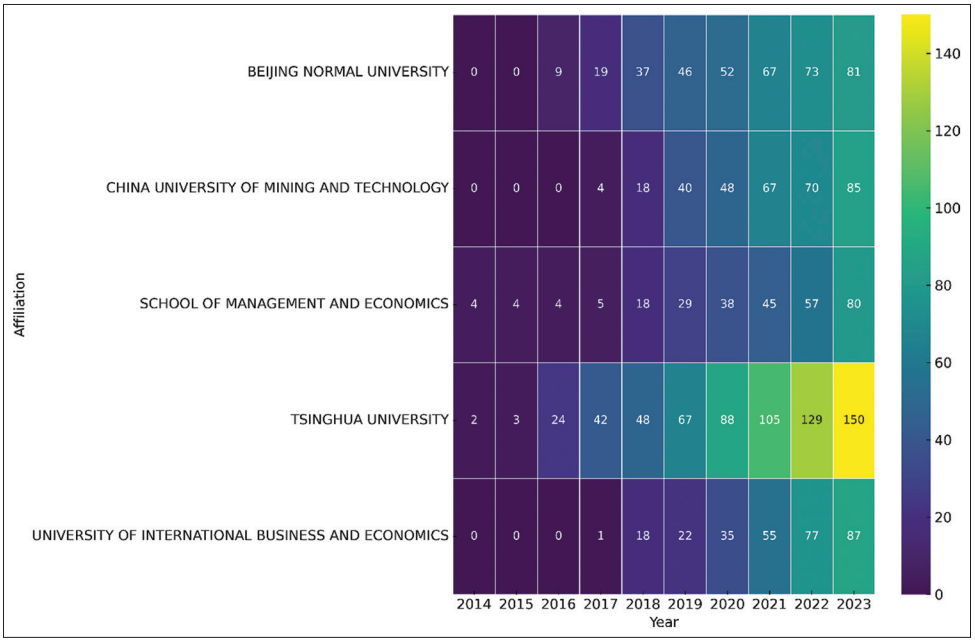


Figure 6: Publication growth by country

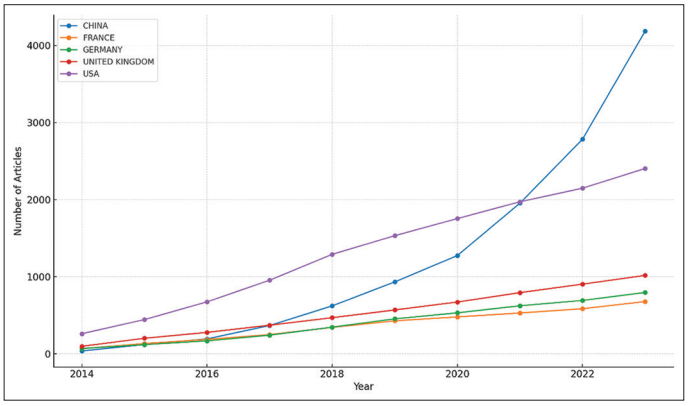
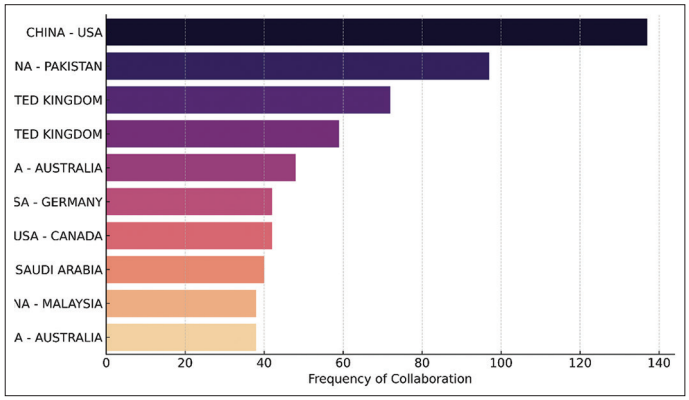


Figure 7: Top collaboration



From the comparison of the two data, there is a general increase in article production across all countries, reflecting a global trend in the growth of scientific research. China's rapid growth in publication volume is a standout, which, when combined with its total citation count, positions it as an emerging powerhouse in global research. The United States maintains a leading position in influence and volume, although the publication growth rate is lower than in China. The United Kingdom effectively balances quantity and quality, with a high average citation count indicating significant research impact. Germany and France maintain consistent growth, with Germany showing a slightly higher trajectory in research output and impact.

Figure 7 presents the top 10 collaborations and highlights various significant aspects of the dynamics of international collaboration. There is a noticeable prevalence of particular partnerships, with specific pairs of countries exhibiting a significantly greater collaboration frequency than others. This phenomenon can indicate bilateral solid relations, substantial mutual interests, or large-scale projects involving these countries. Furthermore, geopolitical and economic factors substantially influence the determination of this collaboration pattern. The frequent collaboration between specific pairs of countries often indicates robust economic interconnections or intertwined geopolitical interests. This phenomenon is frequently observed in countries with extensive trade relations or are bound by political agreements, as these tend to exhibit higher levels of collaboration. Furthermore, this analysis also demonstrates the sector's reliance on this collaboration. The extensive level of collaboration between two countries may indicate a reliance or intensive cooperation

Table 2: Top 10 countries by total citation

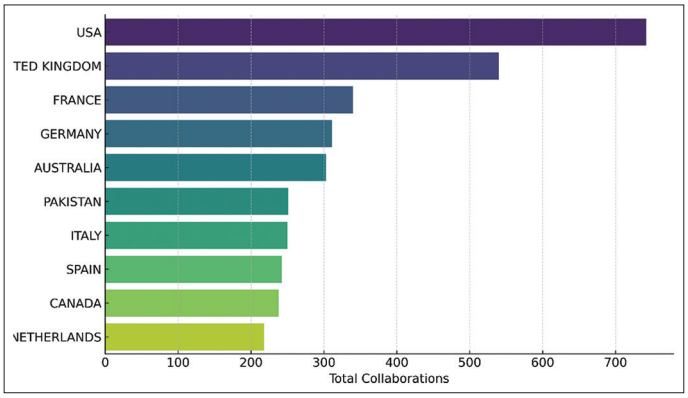
Country	Total citation	Average article citations
China	31773	28.40
USA	14753	23.60
United Kingdom	9748	40.00
Germany	5240	21.10
Australia	5198	31.10
France	4765	24.40
Italy	4067	27.50
Spain	3657	27.30
Canada	3159	24.50
Sweden	3135	49.80

in specific sectors, such as technology, defense, or research and development.

Figure 8 displays the ten countries with the highest number of collaborations. Various crucial elements reflect the dynamics of international relations and global politics. Including countries on this list frequently signifies their status as prominent actors with substantial economic influence in the global political sphere. Their participation in numerous collaborations demonstrates their prominent position in addressing global issues. Furthermore, these countries exhibit many differences and extensive cooperation across numerous nations and disciplines. This could indicate a proactive approach to foreign policy and endeavors to diversify their international relations. Furthermore, the leading position in overall collaboration can also indicate the presence of substantial resources and advanced technical capabilities, enabling these countries to participate in large-scale projects or multilateral initiatives.

Out of the journals examined, the "Journal of Cleaner Production" exhibits a noteworthy and steady rise in publications. This indicates a burgeoning interest and research emphasis, propelled by a rising awareness and apprehension regarding environmental matters and sustainable methodologies. In contrast, the journals Business Strategy and the Environment and Technological Forecasting and Social Change exhibit consistent publication counts, suggesting a consistent but specialized interest in their respective fields or the potential for broader coverage of these topics in other journals. The "Operations Management Research journal shows no substantial growth in publications, suggesting a more developed or stable field with well-established research areas. The "International Journal of Production Economics exhibits an initially ambiguous trend but has experienced a slight upward trajectory in recent years. This phenomenon can be ascribed to an increasing fascination with production economics, potentially influenced by global economic shifts and difficulties. Figure 9 contains the most pertinent source.

Figure 8: Top 10 countries by total collaborations



When comparing the journals, the "Journal of Cleaner Production" stands out with its notable increase in publications, suggesting factors such as the increasing relevance of its field, a broadening scope, or its popularity as a preferred journal for related publications. These observations provide valuable insights into the publication trends and dynamics within specific research areas covered by the analyzed journals.

In Table 3, we present the source impact of each journal, which we will afterward compare with the source production over time to assess the relationship between the two variables.

The correlation between a journal's publication output and the frequency of citations for its articles is intricate. It implies that the number of publications alone does not solely determine the number of citations. The articles' quality and relevance are pivotal factors influencing citations, suggesting that the number of publications does not exclusively determine citation impact.

The h-index is a quantitative measure used to evaluate the productivity and citation influence of a scientist, scholar, or journal. The second plot demonstrates the correlation between the overall number of publications and the h-index of each journal. As with the previous observation, it is evident that the h-index does not exhibit a consistent correlation with the number of publications. This underscores that the influence, as quantified by the h-index, is not exclusively determined by the number of papers published.

Figure 9: Most relevant source

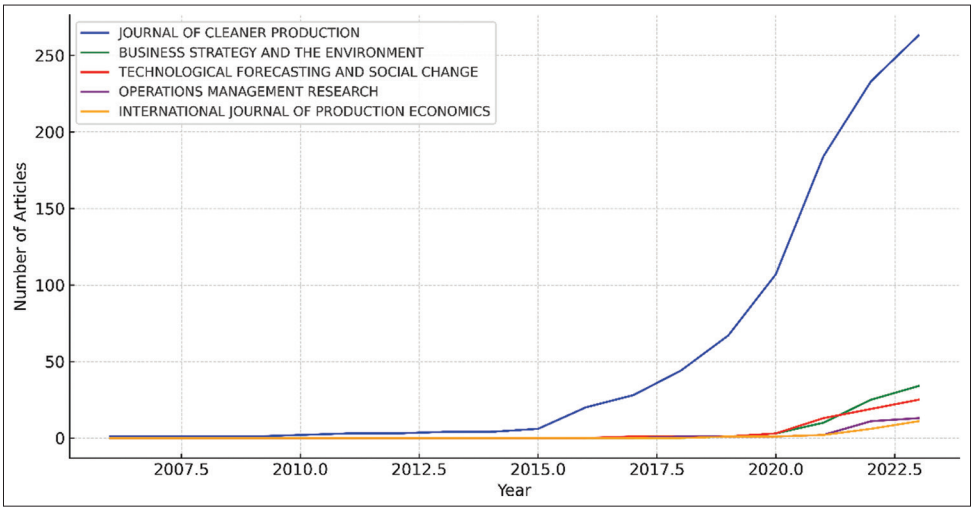


Table 3: Source production over time

Source	H-index	G_index	M_index	T.C	N.P	PY-start
Circular economy and sustainability	6	7	2	67	20	2021
Journal of cleaner production	3	4	3	26	28	2023
Sustainability (Switzerland)	3	3	3	20	42	2023
Chemical engineering journal	2	3	2	10	6	2023
Coatings	2	2	2	5	4	2023
Desalination	2	3	2	9	4	2023
Energy	2	3	2	13	6	2023
Environmental technology and innovation	2	2	2	8	4	2023
Frontiers in sustainability	2	6	0.667	82	6	2021
Fuel	2	3	2	9	4	2023

H-index: Measures an author's impact by the number of papers with equivalent citations. G-index: Focuses on highly-cited papers to assess impact. G-index: Focuses on highly-cited papers to assess impact. M-index: Normalizes the H-index for career length. T.C.: Total citations for all an author's papers. N.P.: Author's total number of publications. PY-Start: Year of the author's first publication.

However, the determination is contingent upon the impact and importance of these papers within their respective domains.

The quantity of publications in a journal occasionally aligns with a correspondingly substantial cumulative citation count or h-index. This becomes apparent when analyzing journals that have a significant quantity of publications but relatively lower impact metrics. Conversely, some journals with fewer publications may have relatively high impact metrics, suggesting their articles are exceptional or highly sought after within their academic community. Hence, the measure of a journal's significance and sway lies not in the sheer number of publications but instead in the caliber and desirability of its articles among academics.

The particular domain of the journal can additionally impact the relationships above. Various academic disciplines may employ different citation practices, resulting in varying citation counts. Specific fields can have higher citation counts, indicating a more significant number of references to their published articles. In comparison, other fields may have lower counts despite producing articles of high quality. Furthermore, the metrics can also be influenced by the changing research trends and evolving interests of the academic community. For instance, journals in burgeoning fields may rapidly increase citations and h-index despite having fewer publications. Hence, it is imperative to consider the specific dynamics of the field and the changing nature of research when assessing the correlation between the number of publications, citation counts, and impact metrics.

We performed a network analysis by employing a co-occurrence method, establishing a minimum threshold of 100 for the occurrence of keywords. Establishing this threshold is rigorously filtering the keywords in the dataset. Using this approach, we discovered 122 keywords that satisfied the predetermined criteria out of a total of 23,621 keywords that were examined. Figure 10 depicts a visual representation of the network using co-occurrence as the basis.

The blue cluster centers around the correlation between the economy and the environment, specifically highlighting the consequences of climate change. The presence of terms like "environmental economics," "climate change," and "ecological economics" suggests the presence of extensive studies on the impact of environmental factors, particularly climate change, on the economy. This cluster emphasizes the significance of sustainable economic strategies that effectively address environmental challenges, including preserving ecosystem services and implementing policies that facilitate climate change adaptation and mitigation.

The red cluster investigates the interplay among carbon emissions, economic growth, and socio-economic impacts. The text encompasses critical terms such as "carbon emissions," "carbon dioxide," "economic growth," and "green economy," demonstrating the difficulties of decreasing emissions while sustaining economic progress. This cluster highlights the necessity for research on approaches that effectively reconcile environmental preservation and social equity, promoting the shift towards a sustainable green economy that prioritizes sustainability and environmental harm mitigation.

The yellow cluster emphasizes the concepts of "sustainable development" and "sustainability," underscoring the significance of managing environmental impact and implementing sustainable management practices. This cluster highlights the significance of adopting a comprehensive approach to development that incorporates environmental, social, and economic dimensions, as evidenced by the inclusion of keywords such as "environmental impact," "environmental management," and "circular economy." This study investigates strategies for achieving development while minimizing environmental impact, resulting in the development of innovative and sustainable solutions.

The primary emphasis of the green cluster is on environmental policies and regulations. The presence of keywords such as "environmental policy," "emission control," "environmental regulation," "environmental protection," and "environmental tax" suggests that the research focuses on evaluating the efficacy of different policy instruments in tackling environmental issues. This cluster pertains to the necessity of comprehending the efficacy of policies and regulations in diminishing pollution, promoting sustainable practices, and safeguarding natural resources, all while ensuring fairness and social well-being.

Utilizing the document analysis unit in VOS viewer, bibliometric coupling analysis is advantageous for visualizing and comprehending connections among documents by examining similarities in their reference lists. This approach discerns

correlations among documents, whereby documents exhibiting numerous shared references tend to encompass comparable subjects or fields of study. Describing the research structure in a specific field is advantageous as it aids in identifying noteworthy clusters or sub-topics in the literature. Moreover, this analysis enables the identification of research trends and patterns, emphasizing pivotal documents that may have a significant impact or significance in the field of study. Therefore, bibliometric coupling analysis is a crucial tool for researchers, enabling a thorough and detailed literature review process and ensuring efficient identification of all essential and relevant works on a given topic. We conducted a bibliographic coupling analysis using documents as the unit of analysis. We set a minimum threshold of 100 citations per document, resulting in 250 thresholds out of 5302 documents. Figure 11 depicts a bibliographic coupling between two documents.

Different node colors represent multiple clusters. These clusters may represent distinct research subfields or subjects within a broader discipline. Clusters characterized by more prominent and more densely connected nodes suggest research areas that are more advanced or encompass a significant amount of interconnected literature.

Interconnecting lines between distinct clusters signify the exchange of ideas and collaboration among research participants or the integration of different academic disciplines. Interdisciplinary

Figure 10: Co-occurrence visualization

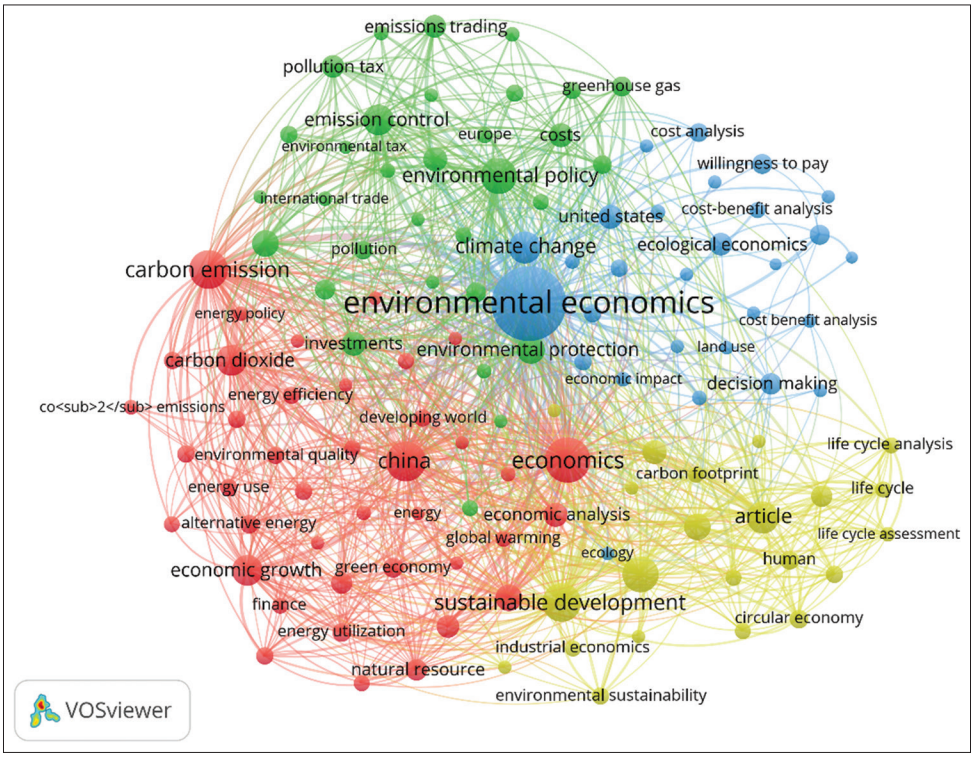
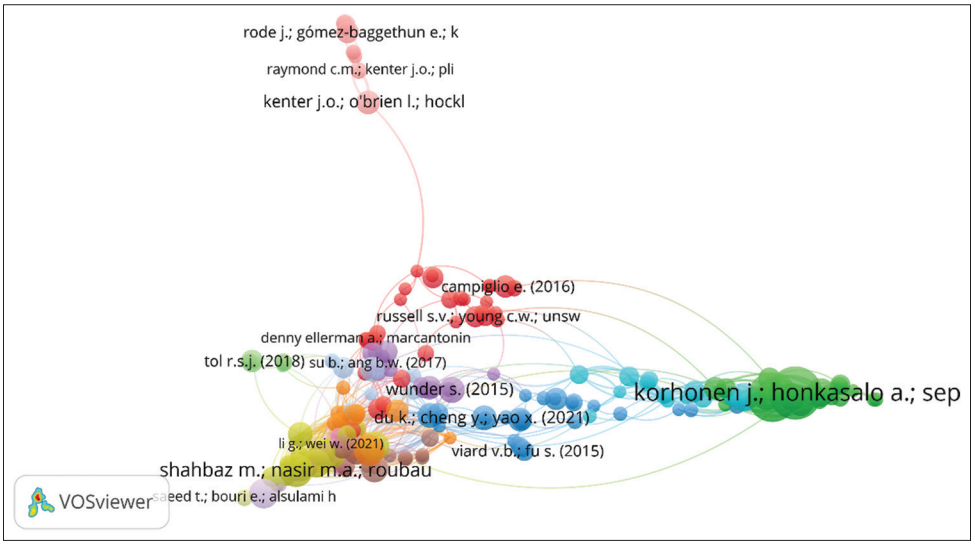


Figure 11: Bibliographic coupling



documents serve as crucial conduits that connect disparate clusters within the realm of research. Documents that exhibit numerous connections, such as larger nodes or a greater number of interconnected lines, tend to receive significant citations as pivotal works in the field. These documents can significantly impact the research trajectory or be regarded as significant literature in the field.

Documents possessing elevated "Weight_Citations" and "Score_Citations" are deemed crucial within the academic community due to their frequent utilization as primary references and their substantial impact and relevance. An illustrative instance is the study by Korhonen et al. in 2018. It garnered considerable acclaim with 1722 citations, underscoring its significance and impact on environmental economics. The 2017 publication by Murray A., Skene K., and Haynes K. has gained significant acclaim, as evidenced by its 1473 citations, for emphasizing the significance of their findings and methodology. Shahbaz et al. 2018 have made significant and well-regarded contributions to environmental economics. Their research has been cited 687 times, which confirms its relevance in academic discussions. The research conducted by Ahmed Z., Asghar MM, Malik MN, Nawaz K., has received significant attention in the environmental economics literature, with 583 citations (Ahmed et al., 2020). These works are frequently referenced as essential contributions to the field. These documents frequently include groundbreaking methodologies, paradigm-shifting findings, or thorough literature reviews, all of which contribute to the ongoing advancement of research in environmental economics.

5. CONCLUSION

In conclusion, this bibliometric analysis has illuminated several key environmental economics research landscape dimensions. The growing volume of literature in this field, with a pronounced emphasis on climate change, carbon emissions, sustainable development, and environmental policy, underscores the increasing relevance of these topics. The concentration of academic output among a smaller cohort of authors, as revealed by applying Lotka's Law, suggests a high impact of particular researchers and the potential for expanded collaboration in future studies.

Further, our institutional and country-level analysis has identified a significant rise in publications across various affiliations and countries, most notably in China, mirroring the global expansion of research in environmental economics. This trend is also reflected in the escalating number of publications in critical journals such as "The Journal of Cleaner Production," highlighting a broader scientific commitment to environmental issues and sustainable practices. Our research has also delineated several distinct clusters focusing on various aspects of environmental economics. These clusters encompass a range of topics, from the economic implications of climate change and carbon emissions to sustainable development and environmental policy and regulation, indicating a diverse and multi-faceted research field.

However, it is imperative to acknowledge the limitations of this study, primarily its reliance solely on data from Scopus. This approach may have restricted our view of the field's full research dynamics. Therefore, future research should consider incorporating data from other reputable international indices, such as the Web of Science (WoS), to achieve a more comprehensive understanding.

We recommend that subsequent research continues to focus on under-explored areas within environmental economics. Adopting interdisciplinary approaches is particularly recommended, given the environmental challenges' global and complex nature. Furthermore, the fluid and evolving nature of environmental issues necessitates that researchers remain agile, continuously updating their analyses to capture new trends and shifts in this vital field.

REFERENCES

Aboagye, E.A., Chea, J.D., Lehr, A.L., Stengel, J.P., Heider, K.L., Savelski, M.J., Slater, C.S., Yenkie, K.M. (2022), Systematic design of solvent recovery pathways: Integrating economics and environmental metrics. ACS Sustainable Chemistry and Engineering, 10(33), 10879-10887.

Apriantoro, M.S., Herviana, J., Yayuli, Y., Suratno, S. (2023), Sharia financial literacy: Research trends and directions for future inquiry. Journal of Islamic Economic Laws, 6(2), 19-40.

Apriantoro, M.S., Suryaningsih, A., Muthoifin, M. (2023), Bibliometric Analysis of Research Development of Economic Dispute Settlement. In: Proceedings of the 5th International Graduate Conference in Islam and Interdisciplinary Studies, IGCIIS 2022, 19-20 October 2022, Mataram, Lombok, Indonesia.

Cabanillas-Lazo, M., Quispe-Vicuña, C., Barja-Ore, J., Fernandez-Giusti, A., Munive-Degregori, A., Retamozo-Siancas, Y., Guerrero, M.E., Mayta-Tovalino, F. (2022), A 10-year bibliometric analysis of global research on gut microbiota and Parkinson's disease: Characteristics, impact, and trends. Biomed Res Int, 2022, 4144781.

Cudjoe, D. (2023), Energy-economics and environmental prospects of integrated waste-to-energy projects in the Beijing-Tianjin-Hebei region. Environment, Development and Sustainability, 25(11), 12597-12628.

Degirmencioglu Aydin, N., Aydin, M. (2023), An environmental impact assessment of major economic sectors in Turkey: Economics and law perspective. Journal of the Knowledge Economy. https://doi.org/10.1007/s13132-023-01400-y

Eaton, E., Hunt, A., Black, D. (2023), Developing and testing an environmental economics approach to the valuation and application of urban health externalities. Frontiers in Public Health, 11, 1070200.

Gaur, V.K., Gautam, K., Sharma, P., Gupta, S., Pandey, A., You, S., Varjani, S. (2022), Carbon-based catalyst for environmental bioremediation and sustainability: Updates and perspectives on techno-economics and life cycle assessment. Environmental Research, 209, 112793.

Jung, H., Song, C.K. (2023), Effects of emission trading scheme (ETS) on change rate of carbon emission. Scientific Reports, 13, 912.

Khan, M.K., Zahid, R.M.A., Shahzad, K., Hussain, M.J., Kitendo, M.M. (2022), Role of managerial ability in environmental, social, and economics sustainability: An empirical evidence from China. Journal of Environmental and Public Health, 2022, 8588385.

Khoirunisa, A., Rohman, F., Azizah, H.A., Ardianti, D., Maghfiroh, A.L., Noor, A.M. (2023), Islam in the amid AI. (Artificial intelligence) struggles: Between opportunities and threats. Suhuf, 35(1), 45-52.

Larnaudie, V., Ferrari, M.D., Lareo, C. (2022), Switchgrass as an alternative biomass for ethanol production in a biorefinery: Perspectives on technology, economics and environmental sustainability. Renewable

and Sustainable Energy Reviews, 158, 112115.
Majdawati, A., Annisa, A. (2022), Correlation of chest radiography of confirmed COVID-19 patients with comorbid hypertension and diabetes mellitus. Bali Medical Journal, 11(3), 1644-1648.
Maris, M. (2022), Economics of sustainable development and its environmental impact in the European Union: Case study. Ecocycles, 8(2), 37-46.
Nyeko, S.J., Mlay, S.V., Judith, A., Nyero, A.I. (2022), Towards a sustainable electronic waste management in Uganda: A stakeholder perspective. African Journal of Environmental Science and Technology, 16(6):238-251.
Petrovic, N. (2022), Why do environmental and ecological economics diverge? Comparison of the ideological, institutional and scientific backgrounds of the main actors. Science and Technology Studies, 35(1), 35-57.
Praveenkumar, S., Agyekum, E.B., Kumar, A., Ampah, J.D., Afrane, S., Amjad, F., Velkin, V.I. (2022), Techno-economics and the identification of environmental barriers to the development of concentrated solar thermal power plants in India. Applied Sciences (Switzerland), 12(20), 10400.
Ramstetter, L., Rupprecht, S., Mundaca, L., Osika, W., Stenfors, C., Klack, J., Wamsler, C. (2023), Fostering collective climate action and leadership: Insights from a pilot experiment involving mindfulness and compassion. iScience, 26(3), 106191.
Rehman, A.U., Ullah, Z., Shafiq, A., Hasanien, H.M., Luo, P., Badshah, F. (2023), Load management, energy economics, and environmental protection nexus considering PV-based EV charging stations. Energy, 281, 128332.
Ryter, J., Fu, X., Bhuwalka, K., Roth, R., Olivetti, E. (2022), Assessing recycling, displacement, and environmental impacts using an economics-informed material system model. Journal of Industrial Ecology, 26(3), 1010-1024.
Safiullin, L.N., Galiullina, G.K., Shabanova, L.B. (2016), State of the market production standards "halal"in russia and tatarstan: Hands-on review. Academy of Marketing Studies Journal, 20, 88-95.
Tariq, S., Safder, U., Yoo, C. (2022), Exergy-based weighted optimization and smart decision-making for renewable energy systems considering economics, reliability, risk, and environmental assessments. Renewable and Sustainable Energy Reviews, 162, 112445.
Thoy, E.W., Go, Y.I. (2022), Enhancement and validation of building integrated PV system: 3D modelling, techno-economics and environmental assessment. Energy and Built Environment, 3(4), 444-466.
Wongrak, G., Hur, N., Pyo, I., Kim, J. (2021), The impact of the EU IUU regulation on the sustainability of the thai fishing Industry. Sustainability, 13(12), 6814.
Zemo, K.H., Termansen, M. (2022), Environmental identity economics: An application to farmers' pro-environmental investment behaviour. European Review of Agricultural Economics, 49(2), 331-358.
Zhang, S., Xiong, K., Fei, G., Zhang, H., Chen, Y. (2023), Aesthetic value protection and tourism development of the world natural heritage sites: A literature review and implications for the world heritage karst sites. Heritage Science, 11(1), 30.
Zhu, Y., Tan, J., Cao, Y., Liu, Y., Liu, Y., Zhang, Q., Liu, Q. (2022), Application of fuzzy analytic hierarchy process in environmental economics education: Under the online and offline blended teaching mode. Sustainability, 14(4), 2414.
Zhu, Z., Jin, Y., Su, Y., Jia, K., Lin, C.L., Liu, X. (2022), Bibliometric-based evaluation of the neuromarketing research Trend: 2010-2021. Frontiers in Psychology, 13, 872468.
Ziabina, Y., Pimonenko, T., Lyulyov, O., Us, Y., Proshkin, D. (2021), Evolutionary development of energy efficiency in the context of the national carbon-free economic development. E3S Web of Conferences, 307, 09002.