mathematics

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Review

A Decade for the *Mathematics*: Bibliometric Analysis of Mathematical Modeling in Economics, Ecology, and Environment

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Abstract: Our study commemorates this event by presenting a retrospective of the publications related to the use of mathematical tools for the analysis of economic, ecological, and environmental phenomena. We analyzed 1257 scientific publications using bibliometric techniques to examine the most productive and influential authors and their contributions in the economic, ecological, and environmental fields. Co-authorship among the top authors and countries, co-occurrence of the keywords, bibliographic coupling of the documents and authors, and author co-citation were analyzed by applying network analysis techniques using VOSviewer software, identifying the intellectual structure of the research and the collaborative networks in the fields. The results show that mathematics has grown impressively in terms of publication and citation. The contributions come from all over the world, but the majority are from the People's Republic of China and Spain. The results also show themes and trends in the economic, environmental, and ecological fields and a predominant use of mathematical tools in optimization processes in order to rigorously substantiate the decisions of investors and policymakers. Thus, our study offers support for any researcher to understand the current state of the art and develop a comprehensive understanding of journal publications.

Keywords: *Mathematics*; Web of Science; bibliometry; economics; environmental; ecological

MSC: 00A05

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1. Introduction

In recent years, bibliometric analysis has become increasingly popular in economic research, as it is considered a convenient approach to identify trends in the performance of journals or articles, the intellectual structure of a field in the existing literature, or patterns of collaboration [1,2]. The popularity of bibliometric analysis is due to the availability of numerous databases (Web of Science, Scopus, Direct Science, etc.) and numerous software that allow the analysis of large volumes of data (VOSviewer, Leximancer, HistCite, etc.). Thus, it has been used in various areas such as corporate social responsibility [3], strategic management [4], the impact of COVID-19 [5], medicine [6,7] and corporate universities [8]. To the best of our knowledge, no article has bibliometrically studied the publications related to the use of mathematical tools for the analysis of economic, ecological, and environmental phenomena. To fill this gap, we chose the mathematics journal (ISSN 2227-7390) among the Web of Science indexed journals. *Mathematics* is a peer-reviewed, open access journal, that publishes high-quality research in all areas of pure and applied mathematics. Furthermore,

this journal has published numerous economic research articles over time, having opened more than 50 special issues in 2022 related to the economic area.

The first issue of the journal was published in March 2013. Since then, it has published more than 10,000 papers from more than 16,800 authors. Over the years, the journal has received high ratings according to various qualitative and quantitative measures. Thus, *Mathematics* secured its place at 21/332 (Q1) in the mathematics category. This ranking claims that the journal publishes rigorous, high-quality papers. According to Clarivate Analytics, the journal's impact factor in 2021 was 2592, meaning that the articles published in 2019 and 2020 received an average of 2592 citations in 2021 alone from the sources that Clarivate Analytics indexes. According to Scopus, the journal has a CiteScore of 2.9 and a Source Normalized Impact per Paper (SNIP) of 1.162, which means that the articles published between 2018 and 2021 received an average of 2.9 citations in 2021 alone, which is 1.162 times the average citations articles in its field receive. The journal has an h-index of 43, which means that at least 43 of the journal's publications have been cited 43 times. These values indicate the journal's high reputation among researchers.

The year 2022 marks the 10th anniversary of *Mathematics*. On this occasion, our study aims to provide a bibliographic overview of the journal. Such retrospectives can be found in the literature. For example, [9] provided a comprehensive overview of the forty years of the *International Journal of Information Management*. [10] presented a synthesis of forty years of the Journal of Futures Markets. [11] summarized the forty-five years of the *Journal of Business Research.* Our study presents an in-depth analysis of the publication trends and citation structure of articles published in the *Mathematics* that are related to the analysis of economic, ecological, and environmental phenomena. The most prolific authors on the subject and their affiliated countries are considered. It also traces the major themes/topics discussed in the selected scientific publications, classifies them into clusters, and provides an overview of their content.

Our analysis contributes to the literature by: (1) presenting an overview of the main current research in which mathematical models offer possibilities for the analysis of economic, ecological, and environmental phenomena; (2) highlighting the main articles, authors, countries, and networks in this field by reporting to the journal *Mathematics*; and (3) identifying the main directions in which mathematical tools can be used appropriately and rigorously for economic, environmental, and ecological research.

The rest of the paper is structured as follows. The paper begins with a description of the methodology and the research context, and then we unveil and discuss the results obtained. Finally, we draw conclusions, highlight limitations, and outline future research directions.

2. Materials and Methods

The source of scientific publications included in the analysis has been the academic platform Web of Science, accessed on 9 November 2022. Regarding the topic, the following keywords have been considered relevant: "mathematics economic*", "mathematics environment*", and "mathematics ecologic*". The total sample consists of 1257 (472, 738, 47) scientific publications, the studies being conducted by 4118 authors.

In the first stage, a descriptive bibliometric analysis has been conducted, highlighting yearly trends in publications, the most relevant papers, article and author productivity levels, the most prolific authors and countries, and the most cited documents.

In the next stage, a bibliometric analysis based on network analysis has been carried out. This technique reveals aspects related to the intellectual and the social structures of the fields [12,13].

To investigate the flow of scientific and technical information and to identify a subject area profile for a given research, the co-word analysis technique was performed. Proposed by [14], "co-word analysis is a content analysis technique based on the assumption that the subject of a paper can be summarized in a number of key terms that reflect its core contents" [15]. The identification of a conceptual structure through co-word analysis [16,17] implies that words co-occur in documents if they are related. Knowledge domain visual-

izations by building a semantic map through co-word analysis ensure the understanding of cognitive structure [18] and describe the evolution and current state of the literature on the field [15]. In term co-occurrence analysis, the binary counting method was used, considering 10 the minimum number of occurrences of a term in document titles and abstracts. From the total of particular terms, those that met the threshold were selected. For each of these terms, a relevance score was calculated. Based on this score, the most relevant terms were selected. Furthermore, we designed a keywords co-occurrence analysis, determining the total strength of the co-occurrence links with other keywords and selecting those with the greatest total link strength. We built a network of themes and their relationships, considering that keywords are the central description of the research content. The links between occurring keywords reveal the focal interest of the research topic in the field.

Co-author analysis examines the collaborative networks that scholars create on scientific publications [19]. Co-authorship analyses by author and country were conducted in order to evaluate the link between researchers. The minimum number of documents for an author was 1, and for a country, it was 5. For each of the authors/countries, the total strength of the co-authorship links with other authors/countries was calculated. The authors/countries with the greatest total link strength were selected.

Two publications are bibliographically coupled if they both cite a third publication [20]. It is thus investigated if the bibliographic structure contains a set of properties that characterize the paper from which it derives. "Bibliographic coupling uses the number of references shared by two documents as a measure of the similarity between them" [21]. We conducted a bibliographic coupling analysis by documents and authors.

The co-citation is defined as the frequency with which two documents are cited together [22]. The more two items are cited together, the more their content is related. Co-citation analysis is used to evaluate the intellectual structure of different themes [23]. Co-citation analysis can be conducted at the level of authors and references, identifying key authors and articles and visualizing the intellectual structure of the topic. Using the scientific publications as its source, author co-citation analysis focuses on the intellectual links between authors, identifying a certain thematic similarity, and a high probability of the same research front [24]. By how frequently other writers cite their combined work, two authors are connected through author co-citations. A different perspective on a knowledge structure can be built using author co-citation patterns [25]. We performed an author co-citation, considering 20 the minimum number of citations for an author. For each of the authors, the total strength of the co-citation links with other authors was calculated. The authors with the greatest total link strength were selected.

The data were processed with VOSviewer software tool to construct and view Bibliometric maps.

3. Empirical Results and Discussion

3.1. Descriptive Analysis

The analysis of the scientific publications in *Mathematics* that address the studied topics reveals a preponderance of concerns for environmental (738), followed by economic (472), and then ecological (47) issues. Regarding the type of document, most are articles (1228), noting the existence of a number of 25 review articles and 4 editorial materials. On the structure of the topic, they are presented in Table 1.

Table 1. Types of documents on the topic.

Documents Type	Economic*	Environment*	Ecologic*
article	461	723	44
review article	7	15	3
editorial material	4	-	-

Source: Authors.

The most relevant papers concerning economic issues are those of Santos-Jaen et al. (2022), Owolabi et al. (2022), Shu et al. (2022), Shinkevich et al. (2022), Ayuda et al. (2022), Guo et al. (2022), Balash et al. (2021), Kovacs et al. (2021), Huang et al. (2021), and Cai et al. (2021), these addressing various topics (performance, industrial zones, export, business market profitability, economic risk, patent commercialization performance, and finance), in specific contexts (hotel, chemical industries, agriculture, COVID-19, etc.). Papers such as those of Arav et al. (2022), Ramirez-Carrasco et al. (2022), Trivedi et al. (2022), Qian and Cui (2022), Khan et al. (2022), Liu et al. (2022), Shinkevich et al. (2022), Gocheva-Ilieva et al. (2022), Riou et al. (2022), and Ainapure et al. (2022) are relevant in terms of environmental issues. Targeting ecological issues, the most relevant articles are those of Shinkevich et al. (2022), Carletti and Banerjee (2019), Gutierrez et al. (2022), Vakulenko and Grigoriev (2021), Uso-Domenech et al. (2019), Mondal et al. (2022), Oborny (2018), Yilanci et al. (2022), Abbas and Naji (2022), and Dyvak et al. (2020).

Research productivity, estimated through the number of scientific publications in *Mathematics*, *per year per topic*, is shown in Table 2. The trend line has been plotted in Figure 1, allowing the referral of the issues of interest and providing useful results for both researchers and decision-makers. It can be observed that there is an upward trend in publications, with most papers published in 2022. While the environmental topic is a growing concern in the authors' approaches, the economic topic has decreased as a research objective. The ecological topic is kept at a low level in the research priorities.

Table 2. Scientific publications *per year per topic*.

	Economic*	Environment*	Ecologic*	Total
2017		5		5
2018	7	21	7	35
2019	32	59	3	94
2020	98	116	9	223
2021	176	245	14	435
2022	159	292	14	465
Total	472	738	47	1257

Source: Authors.

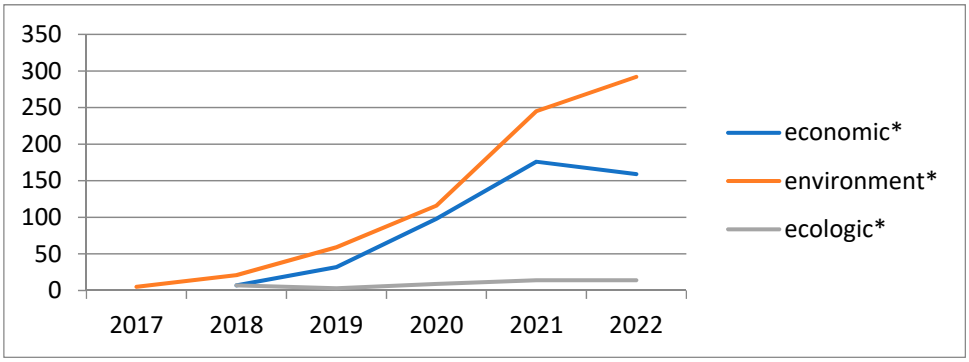

Figure 1. Scientific publications trend.

Author productivity, calculated as number of articles per author, is relatively similar, with a higher value in the economic concerns: a total of 1467 authors presented a 0.3217 average productivity, contributing 472 scientific publications in the economic field over the period under study; 2495 authors conducted 738 studies concerning environmental topics, presenting an average productivity of 0.2958; 156 authors wrote 47 articles on ecological topics, with an average productivity of 0.3013. The authors with the most

scientific publications on these topics in *Mathematics*, are presented in Table 3. Wang Chia-Nan (n = 20) and Sarkar Biswajit (n = 19) are the most prolific authors, addressing both economic and environmental issues. The authors' focus is on the use of mathematical tools for solving economic and environmental problems, providing relevant benchmarks for decision-makers in the matter. The development of approaches by publishing several articles in the field ensures a superior quality of the research and a greater pertinence of the results.

Table 3. Authors with the highest number of articles.

Economic*		**Environment***		**Ecologic***	
Authors	**Publications**	**Authors**	**Publications**	**Authors**	**Publications**
Wang, Chia-Nan	10	Wang, Chia-Nan	10	Banerjee, Malay; Petrovskii, Sergei	2
Sarkar, Biswajit	10	Sarkar, Biswajit	9		
Tarasov, Vasily E.	7	Park, Kang Ryoung	7		
El-Sehiemy, Ragab A.; Hong, Kairong; Abad-Segura, Emilio; Alvarez-Garcia, Jose; Gonzales-Zamar, Mariana-Daniela	4	Akram, Muhammad; Joshi, Gyanendra Prasad	5		
		Leiva, Victor; Dang, Thanh-Tuan; Ali, Ziad M.; Yang, Chunming; Garg, Harish; Chen, Kuen-Suan	4		

Source: Authors.

Regarding economic topics, Sarkar's main concerns have targeted the efficiency of production processes. On this subject, a smart production process where the autonomation policy allows the system to manufacture a defect-free product was developed, determining the maximum profit and the optimal values for buffer inventory, production rate, selling price, and investment for autonomation [26,27]. Furthermore, a single-stage manufacturing method to make a perfect production system without defective items was formulated [28]. With reference to the perishable products with a maximum life span and price-dependent demand and trade credit, in order to maximize the vendor's net profit, the optimum investment under preservation, sales price, and cycle time were calculated using the classical optimization algorithm [29]. Furthermore, a multi-product production process was introduced, based on the advertising- and price-dependent demands of products, in order to reduce the failure rate of the production system under the optimum energy consumption [30]. An important production factor is human capital. Sarkar identified worker's cost of stress by developing a link between economic efficiency and working conditions enhancement, using a sequential quadratic programming to optimize the given nonlinear model for production planning [31]. Addressing the issue of credit policies under an imperfect quality environment, Sarkar and co-authors proposed a supply chain with customer-based two-level credit policies, demonstrating the benefit of shorter contracts, particularly with new retailers, over the expected total profit per unit time [32].

Correlating the economic issue with that of environmental protection, Sarkar analyzed the effects of preservation technology investment on waste generation in a two-echelon supply chain model. A model is proposed to optimize the preservation investment, the number of shipments, and the shipment quantity so that the total cost per unit time of the supply chain is minimized. At the same time, by increasing the lot size, the order cost is also reduced. Complementary to economic benefits, preservation leads to a reduction of solid waste from damaged products, with effects on environmental protection [33]. Furthermore, to address the negative environmental effects of corporate activities, joint inventory and pricing decisions were studied in a multi-echelon CLSC model that considered online to offline (O2O) business strategy. For an imperfect production process, the highest profit is generated when the defect rate follows a uniform distribution [34]. Furthermore, an imperfect manufacturing process produces defective products at an uncertain rate and is

reworked to transform them into perfect quality products and reduce losses. Using the interactive Weighted Fuzzy Goal Programming (WFGP) approach can determine a sustainable lot size, reducing the conflict between economic performance and environmental protection [35].

The studies carried out by Wang Chia-Nan focus on economic and environmental issues. Using DEA Malmquist model, an analysis of the organizational performance measurement of the automakers was conducted, considering the relevant technical efficiency, technological progress, total factor productivity of global automobile manufacturers, and financial indicators (total assets, shareholder's equity, cost of revenue, operating expenses, revenue, and net income) [36]. He assessed the operational efficiency of airport runway configurations considering specific input factors (number of runways, dimension of runways, and airport area) and output factors (annual number of flights and annual number of passengers), using the data envelopment analysis models Charnes, Cooper, and Rhodes (CCR), Banker, Charnes, and Cooper (BCC), Slacks-Based Measure (SBM), and Epsilon-Based Measure (EBM) [37]. Furthermore, he developed a two-stage data envelopment analysis model for measuring the performance efficiency, forecasting, and improving future performance for port industry, indicating that the determinants of growing productivity are the technical efficiency change indexes [38]. The performance of the bank sector was analyzed by a dynamic Slacks-Based Measure model in data envelopment analysis, considering assets, capitalization, and liabilities as inputs, revenue as output, and net interest income as a good link [39]. Regarding the supply chain network design problem, he developed a multi-objective mathematical model to design four-echelon intermodal multi-product perishable supply chain configuration, defining the optimization objective functions as minimizing costs, delivery time, emissions, and the supply-demand mismatch in time. The decisions are approached from a strategic perspective (the location, size of facilities, product flows, and workforce level), and from a tactical perspective (harvest time, delivery time, the delivery route, and mode of transport) [40]. Exploiting a hybrid multi-criteria method, which is fuzzy analytic hierarchy process (FAHP) and fuzzy vlsekriterijumska optimizacija i kompromisno resenje (FVIKOR), he proposed a model for evaluating and selecting the most efficient third-party logistics [41].

In the context of the industrial and manufacturing sector development, which involves high energy consumption, Wang Chia-Nan presented a multi-criterion decision-making model (MCDM) that implemented the grey analytic hierarchy process (G-AHP) method and the weighted aggregates sum product assessment (WASPAS) method for the selection of optimal renewable energy sources for the energy sector in Vietnam [42]. Considering the geographical conditions and that wind energy is a viable option, the author studying the selection of wind turbine suppliers as a complex and multi-criteria decision-making process in uncertain environmental conditions with incidents on the cost reduction of equipment safety and delivery to term, is proposing a fuzzy MCDM model [43]. Under the constraints imposed by sustainable development, companies must focus on issues related to the reduction of CO_2 and toxic emissions, energy use and efficiency, waste generation, and worker health and safety. In this context, Wang Chia-Nan proposed a supplier selection model based on a hybrid multi-criterion decision-making model (MCDM) using a fuzzy analytic hierarchy process (FAHP) and green data envelopment analysis (GDEA) [44]. Furthermore, a stochastic multi-objective optimization model is proposed that aims both at production efficiency under uncertain conditions through the objective function that optimizes the amount of pending orders, machine operation time, and customer satisfaction, as well as ensuring sustainable development, through the correlation of three functions related to optimizing profits, emissions, and changing jobs [45].

The main concern of Tarasov VE is memory in economics, using fractional calculus, which is a theory of integrals, derivatives, sums, and differences of non-integer orders, to cure amnesia in economics [46]. Reviewing the problems and difficulties arising in the construction of fractional-dynamic analogs of standard models by using fractional calculus, Tarasov analyzed the effects of memory and non-locality, distributed lag, and scaling,

and formulating rules (principles) for constructing fractional generalizations of standard models, which were described by differential equations of integer order, highlighting the importance of the derivability principle, the multiplicity principle, the solvability and correspondence principles, and the interpretability principle [47]. Generalizing the standard continuous-time model of Solow and Lucas, he proposed two non-linear models to study the influence of memory effects on the rate of economic growth when other parameters of the model are unchanged [48]. Furthermore, by a generalization of the standard Keynesian macroeconomic model, a mathematical model of economic growth with fading memory and continuous distribution of delay time was proposed [49]. In another study, he analyzed depreciation of a non-exponential type and simultaneously considered memory effects in economics by using the Prabhakar fractional derivatives and integrals [50].

Ref. [51] performed an analytical study of a system with multiple time scales to reveal a sequence of bifurcations that are responsible for the change in the system dynamics from a simple steady state and/or a limit cycle to canards and relaxation oscillations, considering it a more realistic description of ecological dynamics. Furthermore, given that demographic noise is simply the biological or ecological counterpart of intrinsic noise in genetic regulation, [52] proposed a technique to model and simulate demographic noise going backward from a deterministic continuous differential system to its underlying discrete stochastic process, based on the framework of chemical kinetics. Petrovskii Sergei and co-authors studied the movement pattern in the context of trapping, based on the Brownian motion and Levy walks, showing that this controversy can be more superficial than real if the problem is considered in the context of traps and that the whole "Levy or diffusion" debate is rather meaningless unless placed in a specific ecological context [53].

The first ten meso-topics with the most citations are presented in Table 4. The artificial intelligence and machine learning topic is the most cited meso-topic, highlighting its relevance in the study of economic, environmental, and ecological phenomena to identify real-world problems, measure and improve predictive performance, devise innovative solutions, and refine strategies through algorithmic decision-making. Furthermore, considering the approach to multidimensional problems, the numerical methods topic is one of the most cited meso-topics in this research context. Understanding the general trends and patterns requires the use of statistical methods. Regarding the content of the issue, the most cited meso-topics are economics, supply chain logistics, management, power systems electric vehicles and security systems.

Table 4. Citation topics meso by topic.

Economic*		**Environment***		**Ecologic***	
Citation Topics Meso	**Citations**	**Citation Topics Meso**	**Citations**	**Citation Topics Meso**	**Citations**
Economics	87	Artificial Intelligence and Machine Learning	129	Numerical Methods	14
Artificial Intelligence and Machine Learning	54	Supply Chain and Logistics	67	Forestry	5
Supply Chain and Logistics	40	Education and Educational Research	37	Sustainability Science	4
Numerical Methods	26	Numerical Methods	36	Molecular and Cell Biology-Genetics	2
Management	23	Statistical Methods	30	Phylogenetics and Genomics	2
Power Systems and Electric Vehicles	20	Economics	29	Artificial Intelligence and Machine Learning	2

Table 4. *Cont.*

Economic*		Environment*		Ecologic*	
Citation Topics Meso	**Citations**	**Citation Topics Meso**	**Citations**	**Citation Topics Meso**	**Citations**
Sustainability Science	17	Management	29	Supply Chain and Logistics	2
Economic Theory	15	Power Systems and Electric Vehicles	27		
Statistical Methods	15	Security Systems	22		
Security Systems	14	Telecommunications	20		

Source: Authors.

The countries that have devoted most effort to publish in *Mathematics* are the People's Republic of China, followed by Spain, Taiwan, Russia and South Korea (Table 5). China's leading position in scientific production is not surprising. Previous studies have already shown that scientific production in China is growing impressively, and in 2018 the country was the largest producer of SCI-indexed original research articles [54]. However, what is particularly notable is the great effort made by Spain in this area.

Table 5. The most productive countries.

Economic*		Environment*		Ecologic*	
Countries/Regions	**Documents**	**Countries/Regions**	**Documents**	**Countries/Regions**	**Documents**
People's Republic of China	98	People's Republic of China	196	Spain	9
Spain	93	Spain	117	Russia	8
Russia	58	Taiwan	65	People's Republic of China	7
Taiwan	42	South Korea	59	Italy	6
USA	28	Saudi Arabia	44	England	5
Romania	27	India	43	India	5
South Korea	24	Russia	43	Saudi Arabia	3
Saudi Arabia	20	USA	42	USA	3
Chile	18	Pakistan	37	Chile, France, Hungary, Morocco, and South Korea	2
Pakistan	18	Italy	35		

Source: Authors.

The first five most cited articles in *Mathematics*, are presented by topic in Tables 6–8.

Table 6. The first five most cited articles in *Mathematics*, on the topic economics*.

Authors	Title	No.	Citations
Tarasov, VE	On History of Mathematical Economics: Application of Fractional Calculus	Jun 2019 | 7 (6)	53
Nosratabadi, S; Mosavi, A; (. . .); Gandomi, AH	Data Science in Economics: Comprehensive Review of Advanced Machine Learning and Deep Learning Methods	Oct 2020 | 8 (10)	38
Mosavi, A; Faghan, Y; (. . .); Band, SS	Comprehensive Review of Deep Reinforcement Learning Methods and Applications in Economics	Oct 2020 | 8 (10)	37
Batrancea, I; Batrancea, L; (. . .); Rus, MI	Greening the Financial System in USA, Canada and Brazil: A Panel Data Analysis	Dec 2020 | 8 (12)	34
Wang, CN; Nguyen, NAT; (. . .); Lu, CM	A Compromised Decision-Making Approach to Third-Party Logistics Selection in Sustainable Supply Chain Using Fuzzy AHP and Fuzzy VIKOR Methods	Apr 2021 | 9 (8)	33

Source: Authors.

Table 7. The first five most cited articles in *Mathematics*, on the topic environment*.

Authors	Title	No.	Citations
Zhou, QL; Mo, HM and Deng, Y	A New Divergence Measure of Pythagorean Fuzzy Sets Based on Belief Function and Its Application in Medical Diagnosis	Jan 2020 | 8 (1)	59
Zhang, SQ; Gao, H; (. . .); Wei, C	Evaluation Based on Distance from Average Solution Method for Multiple Criteria Group Decision Making under Picture 2-Tuple Linguistic Environment	Mar 8 2019 | 7 (3)	55
Garg, H; Gwak, J; (. . .); Ali, Z	Power Aggregation Operators and VIKOR Methods for Complex q-Rung Orthopair Fuzzy Sets and Their Applications	Apr 2020 | 8 (4)	48
Jin, XB; Yang, NX; (. . .); Kong, JL	Deep Hybrid Model Based on EMD with Classification by Frequency Characteristics for Long-Term Air Quality Prediction	Feb 2020 | 8 (2)	45
Yucesan, M; Mete, S; (. . .); Gul, M	An Integrated Best-Worst and Interval Type-2 Fuzzy TOPSIS Methodology for Green Supplier Selection	Feb 2019 | 7 (2)	44

Source: Authors.

Table 8. The first five most cited articles in *Mathematics*, on the topic ecologic*.

Authors	Title	No.	Citations
Daly, AJ; Baetens, JM and De Baets, B	Ecological Diversity: Measuring the Unmeasurable	Jul 2018 | 6 (7)	96
Farina, A	Ecoacoustics: A Quantitative Approach to Investigate the Ecological Role of Environmental Sounds	Jan 2019 | 7 (1)	23
Pramanik, T; Muhiuddin, G; (. . .); Pal, M	An Extension of Fuzzy Competition Graph and Its Uses in Manufacturing Industries	Jun 2020 | 8 (6)	14
Diele, F and Marangi, C	Geometric Numerical Integration in Ecological Modeling	Jan 2020 | 8 (1)	10
Li, DX; Li, SW; (. . .); Zheng, M	Ecological Performance Optimization of a High Temperature Proton Exchange Membrane Fuel Cell	Jun 2021 | 9 (12)	9

Source: Authors.

3.2. Term Co-occurrence

In order to identify the frequently used and highly connected terms in *Mathematics* related to these three fields of research, we carried out a term co-occurrence analysis.

Economic*

Of the 12540 terms, 236 meet the threshold, and the first 10 most relevant are presented in Table 9.

Table 9. The first ten most relevant terms on the topic economic*.

Term	Occurrences	Relevance	Term	Occurrences	Relevance
numerical example	15	3.53	policymaker	14	2.47
stock market	21	3.53	data envelopment analysis	15	2.36
total cost	11	3.42	dea	15	2.35
volatility	17	3.03	engineering	12	2.30
investor	23	2.99	optimization	30	2.20

Source: Authors.

It was found that the predominant use of mathematical tools in optimization processes was in areas with increased volatility, such as the stock market, in order to rigorously substantiate the decisions of investors and policymakers. Data envelopment analysis (DEA) represents the most relevant method in operations research and economics, allowing the identification of the best-practice frontier.

We used co-occurrence networks to extract and visualize the relationships between terms in *Mathematics* scientific publications (Figure 2).

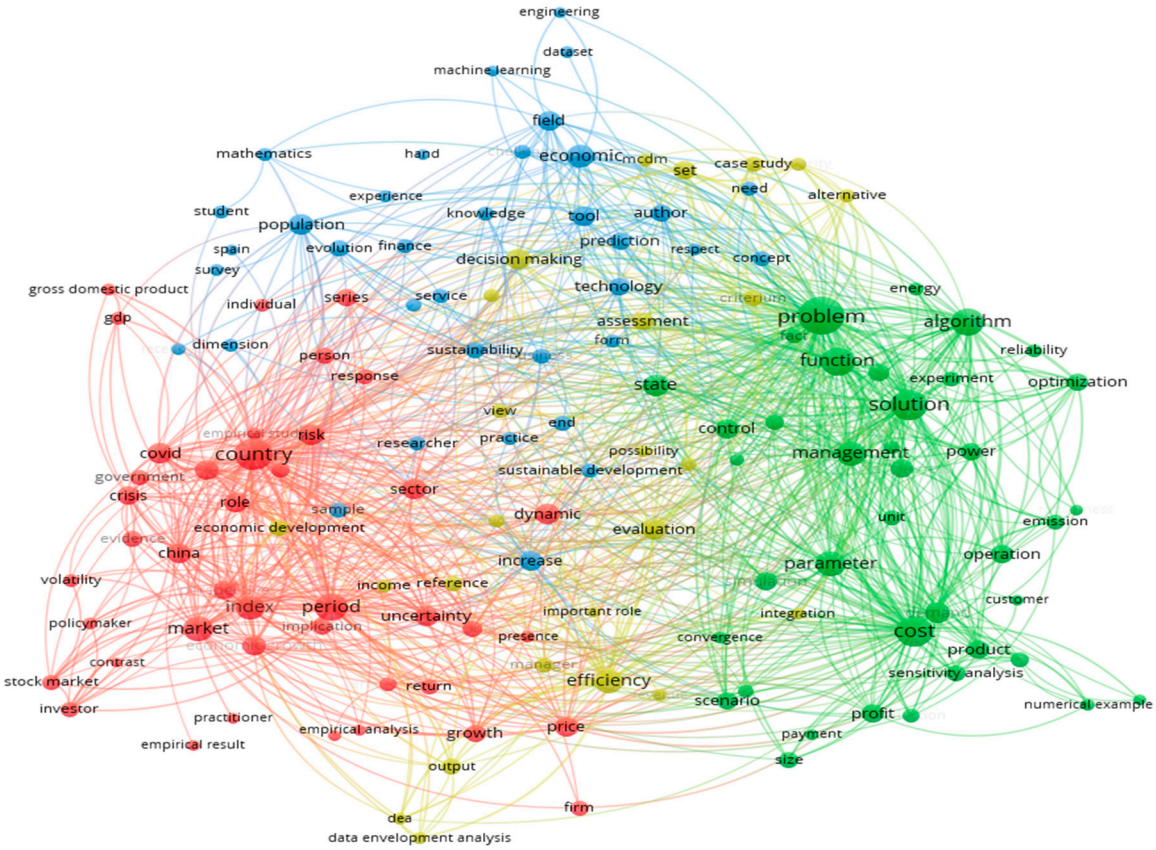

Figure 2. Terms co-occurrence analysis through cartography analysis using VOSviewer (topic economic*).

Four clusters were identified: red (country, market, period, index, dynamic, sector, risk, uncertainty, gdp, investor, volatility, and stock market), green (problem, solution, algorithm, cost, function, parameter, management, state, optimization, control, and energy), blue (economic, population, tool, prediction, technology, and sustainability), and yellow (efficiency, evaluation, assessment, decision making, case study, and alternative).

Environment*

Of the 19,717 terms, 344 meet the threshold, and the first 10 most relevant are presented in Table 10.

Table 10. The first ten most relevant terms on the topic environment*.

Term	Occurrences	Relevance	Term	Occurrences	Relevance
mathematics	22	4.00	image	28	2.93
teacher	21	3.90	iot	16	2.85
cnn	12	3.56	multi criteria decision making	17	2.72
teaching	15	3.47	student	44	2.69
supplier selection	16	2.98	education	22	2.66

Source: Authors.

The terms with the highest co-occurrence reveal the importance of mathematics, technology, and education in solving environmental problems. The convolutional neural network (CNN) is the learning algorithm used in the environmental issues' recognition, classification, segmentation, and identification of specific patterns.

In the co-occurrence network (Figure 3), four clusters were identified: red (algorithm, network, accuracy, field, state, feature, and limitation), green (decision, evaluation, set, criterium, property, case study, and decision making), blue (impact, cost, product, management, industry, emission, and supply chain), and yellow (learning, knowledge, student, and education).

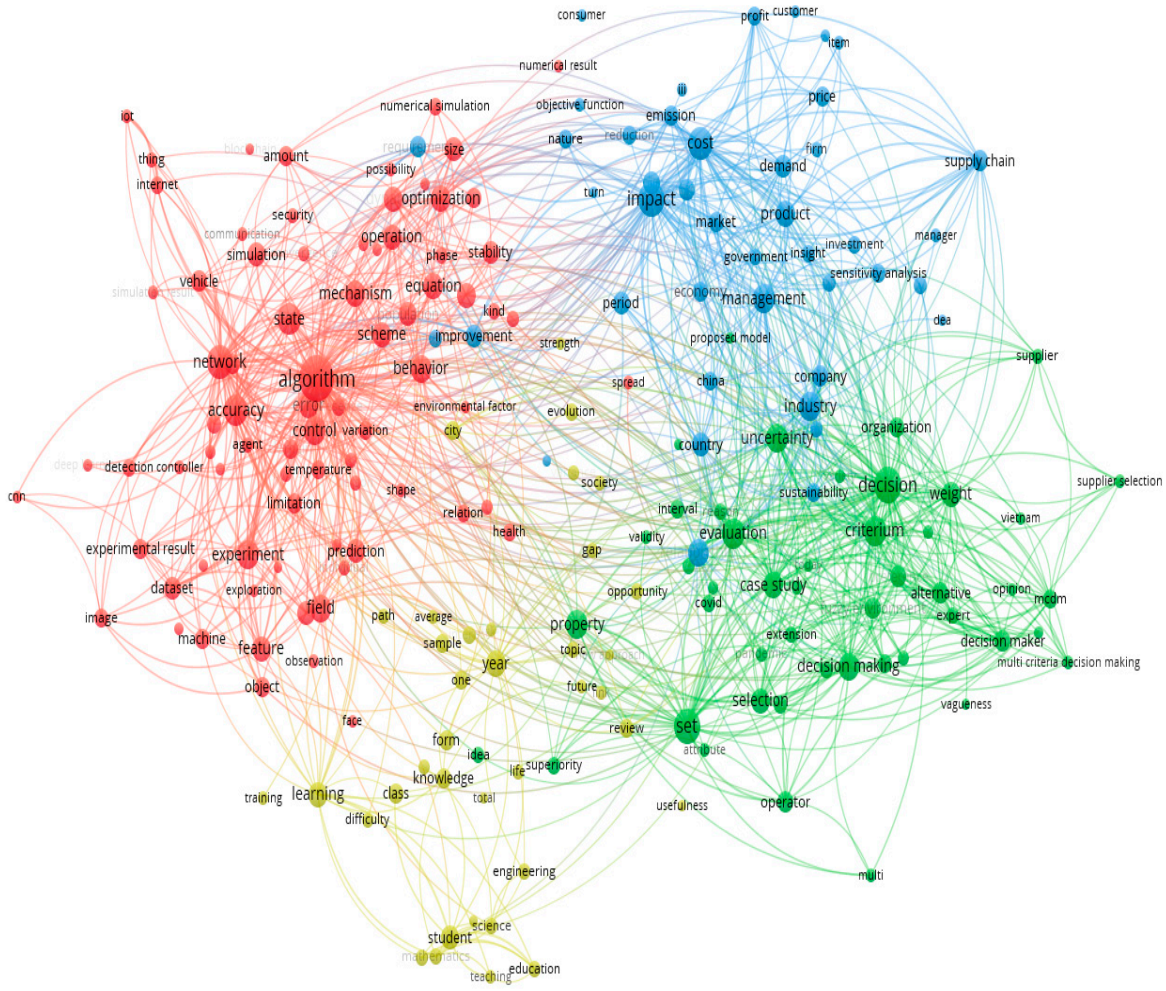

Figure 3. Terms co-occurrence analysis through cartography analysis using VOSviewer (the topic environment*).

Ecologic*

Of the 1643 terms, 3 meet the threshold (Table 11).

Table 11. The most relevant terms on the topic ecologic*.

Term	Occurrences	Relevance
Model	26	1.37
System	23	1.10
Paper	17	0.53

Source: Authors.

With the exception of economic, the first terms according to relevance are not specific to the topic, which reveals the existence of a diversity of addressed issues without explicitly identifying a focus on specific themes.

3.3. Keywords Co-occurrence

To assess the presence, frequency of occurrence, and proximity of keywords across the papers in the fields of economy, environment, and ecology, in *Mathematics*, a co-occurrence analysis was conducted. Understanding the knowledge structure of these scientific fields required the achievement of a keyword co-occurrence network, which ensured the examination of the links between keywords, the mapping of the dynamics of the subject, and the identification of the core research topics.

Economic*

Considering the minimum number of occurrences for a keyword 5 among the 3302 keywords, 109 met the threshold, and the first 10 keywords with the greatest total link strength of the co-occurrence are presented in Table 12.

Table 12. The keywords with the greatest total link strength of the co-occurrence (economic*).

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
performance	40	137	sustainability	17	61
model	47	128	policy	18	59
management	27	79	economics	18	56
impact	24	64	data envelopment analysis	13	52
efficiency	21	63	prediction	15	50

Source: Authors.

Based on the pattern of co-occurrence of pairs of keywords, six clusters were identified, the most relevant keywords being (Figure 4) red (optimization, system, impact, dynamics, stability, prediction, innovation, economic-growth, regression, algorithm, and entropy), green (policy, quality, demand, supply chain, eoq model, and time), blue (machine learning, design, economics, finance, big data, data science, hybrid, network), yellow (performance, efficiency, growth, models, models, forecasting, data envelopment analysis, behavior, and dea), lilac (risk, cointegration, volatility, investment, economic policy uncertainty, sustainable development, CO_2 emissions, return, and liquidity), and turquoise (model, management, selection, sustainability, framework, decision making, ahp, mcdm, performance evaluation).

Environment*

Of the 4920 keywords, 135 met the threshold for a minimum number of occurrences for a keyword 5. The first ten keywords with the greatest total strength of the co-occurrence links with other keywords are presented in Table 13.

Table 13. The keywords with the greatest total link strength of the co-occurrence (environment*).

Keyword	Occurrences	Total Link Strength	Keyword	Occurrences	Total Link Strength
model	62	153	system	40	87
performance	43	134	design	33	82
optimization	44	99	decision making	31	76
selection	27	92	framework	21	63
management	25	88	models	27	60

Source: Authors.

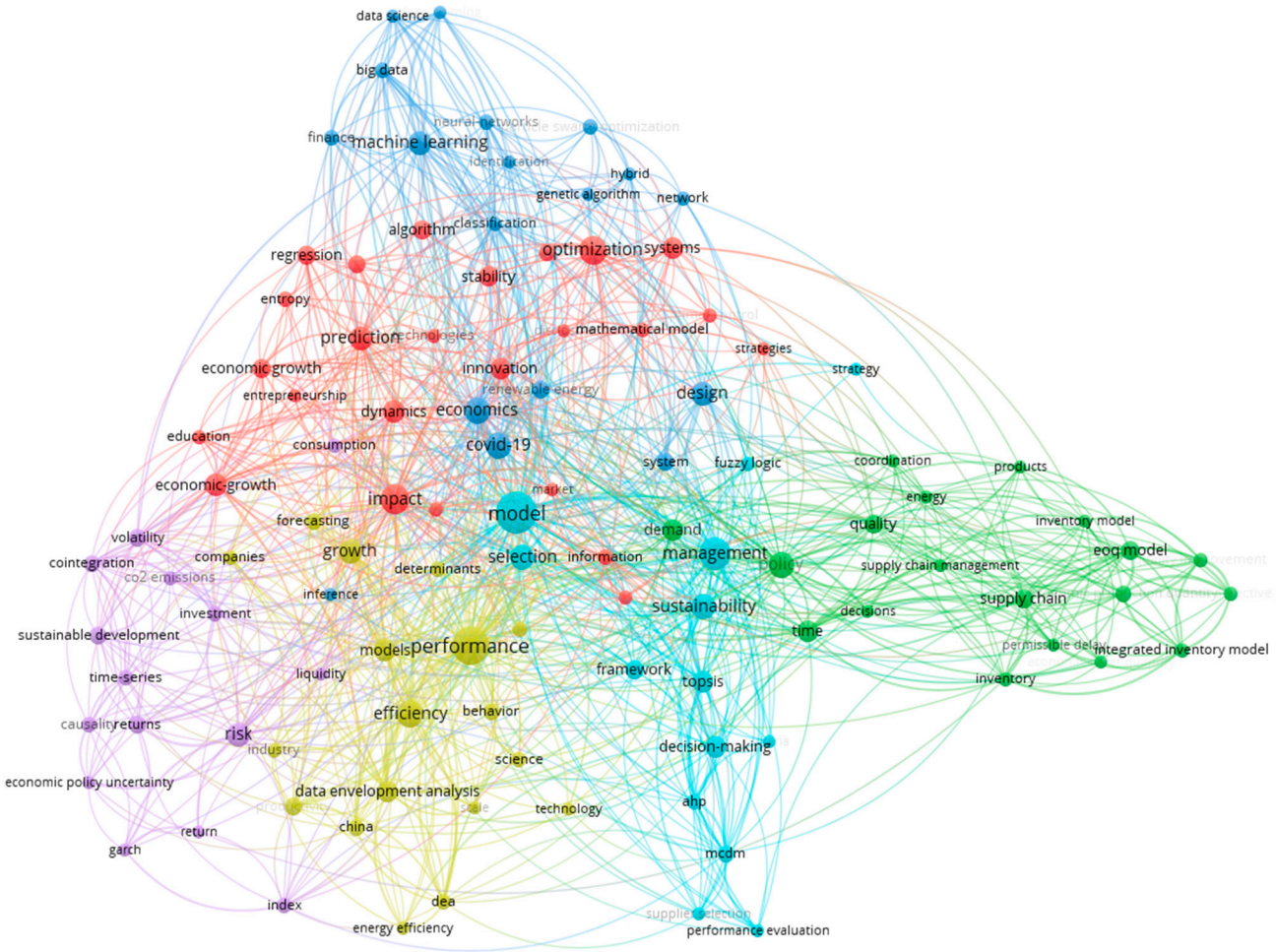

Figure 4. Keywords analysis through cartography analysis using VOSviewer (topic economic*).

The most relevant keywords in the network, structured in seven clusters (Figure 5), are optimization, uncertainty, system, machine learning, prediction, neural network, classification, regression, convergence, and decomposition (red); system, performance, model, efficiency, risk, and network (green); decision making, selection, aggregation-operators, framework, topsis, and entropy (blue); dynamics, design, stability, environment, and simulation (yellow); model, management, impact, behavior, innovation, competitiveness, and determinants (lilac); quality, strategies, supply chain, indicators, eoq model, logistics, and internet (turquoise); and education, students, higher-education, augmented reality, and mathematics (orange). Model, performance, and management represent the common keywords in the economic and environmental topics.

Ecologic*

Of the 431 keywords, 5 recorded a minimum of 3 occurrences (Table 14). Selection and optimization are the common keywords for environmental and ecological issues. Three clusters were delimited in the network: bifurcation and stability; multicriteria decision making and selection; and optimization.

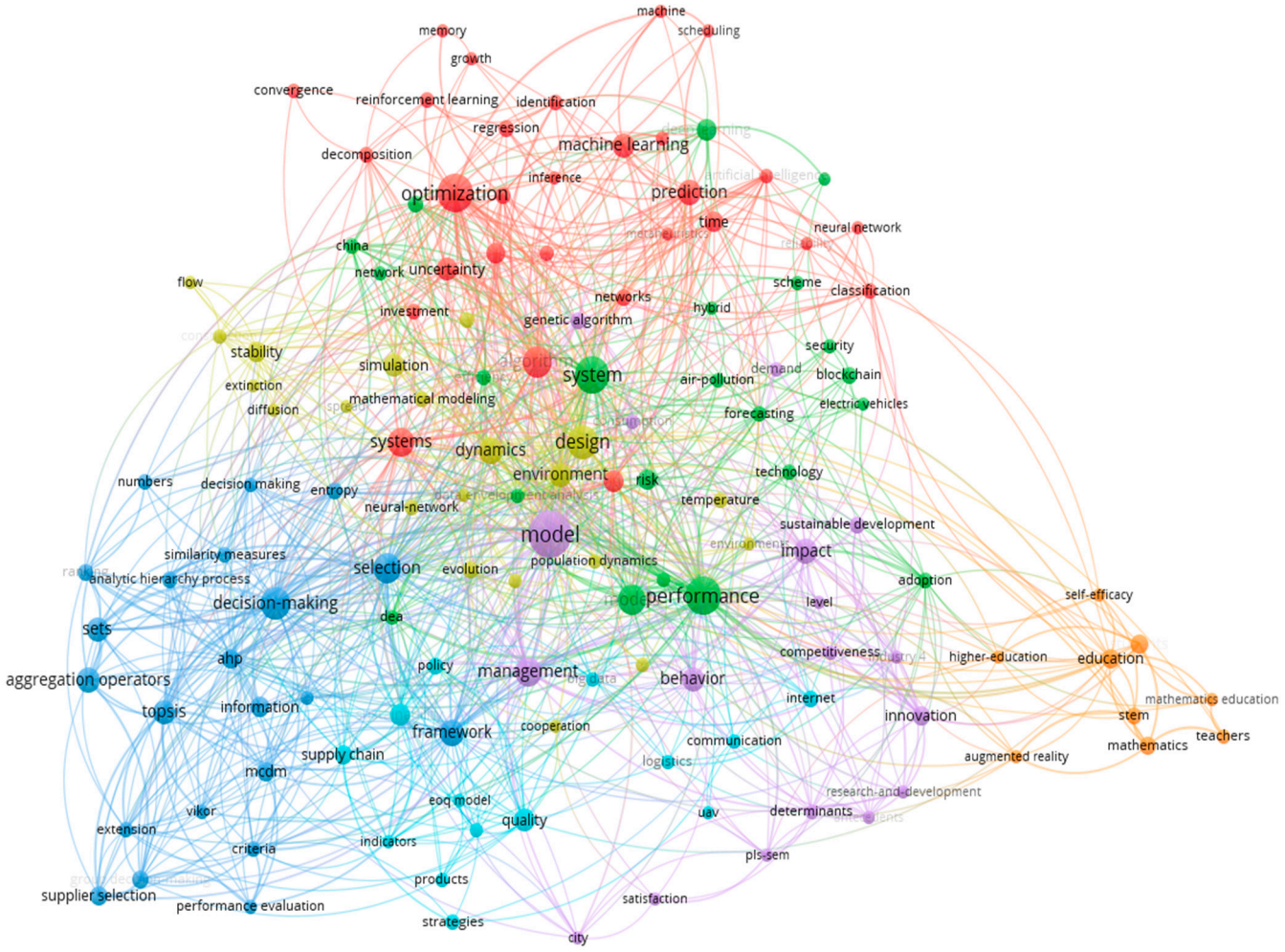

Figure 5. Keywords analysis through cartography analysis using VOSviewer (topic environment*).

Table 14. The keywords with the greatest total link strength of the co-occurrence (ecologic*).

Keyword	Occurrences	Total Link Strength
bifurcation	3	3
multicriteria decision making	3	3
selection	3	3
stability	7	3
optimization	3	0

Source: Authors.

3.4. Co-Authorship

To evaluate the link between researchers, a co-authorship by author and country was conducted.

3.4.1. Co-Authorship—Author

Economic*

Of the 1467 authors, the first 10 with the greatest total link strength are presented in Table 15.

Table 15. The authors with the greatest total link strength (Economic*).

Author	Documents	Citations	Link Strength	Author	Documents	Citations	Link Strength
Wang Chian-Nan	10	87	29	Ghamisi Pedram	2	75	14
Sarkar Biswajit	10	105	21	Mosavi Amirhosein	2	75	14
Alvarez Garcia Jose	6	6	18	Puhong Duan	2	75	14
Zhao Xu	4	16	16	Ahmed Emad M.	2	12	13
Band Shahab S.	2	75	14	Aleem Shady H.E.Abdel	3	30	13

Source: Authors.

The largest set of connected items in the network consists of 27 authors, delimiting six clusters: red (Duc-Thinh Nguyen, Hong-Cham Le, Huong-Thuy Phung, Phi-Hung Nguyen, Thi-Giang Nguyen, Thi-Hoai Tran, and Thi-Ly Nguyen), green (Husain Syed Tam, Kao Jui-Chung, Van Thanh Nguyen, Viet Tinh Nguyen, and Wang Yen-Hui), blue (Dang Thanh-Tuan, Huang Ching-Chien, Kristofer Neal, Lu Chen-Ming, and Nguyen Ngoc-Ai-Thy), yellow (Anh Luyen Le, Minh Nhat Nguyen, Tibo Hector, and Wang Chian-Nan), lilac (Chung Yu-Chi, Nhieu Nhat-Luong, and Pham Huynh-Tram) and turquoise (Day Jen-Der, Quoc-Chien Luu, and Thi-Kim-Lien Nguyen). The key collaborative networks among authors are depicted in Figure 6.

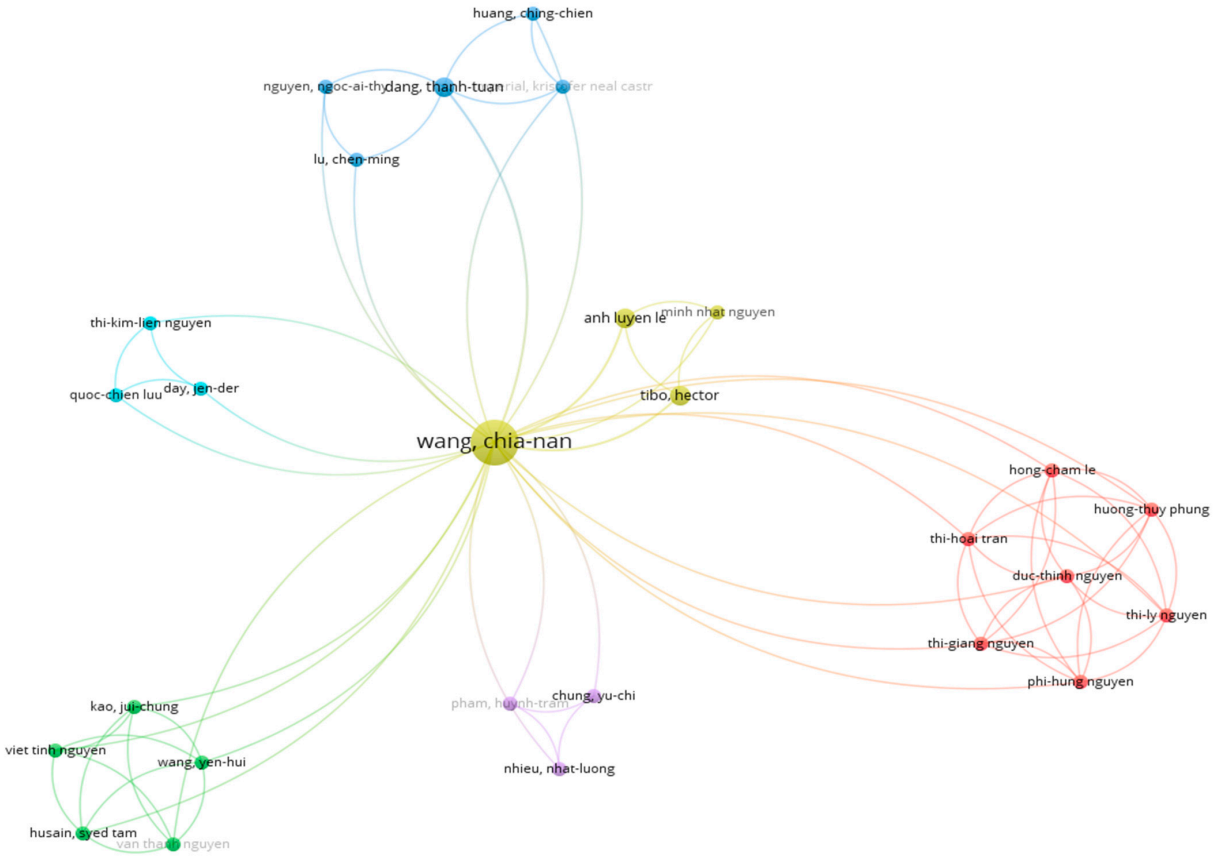

Figure 6. The key collaborative networks among authors (economic*).

Environment*

Of the 2495 authors, the first 10 with the greatest total link strength were selected (Table 16).

Table 16. The authors with the greatest total link strength (environment*).

Author	Documents	Citations	Link Strength	Author	Documents	Citations	Link Strength
Johi Gyanendra Prasad	5	28	21	Rahmani Amir Masoud	3	13	18
Raboaca Maria Simona	3	3	21	Agrawal Smita	2	0	16
Park Kang Ryoung	7	6	20	Alqahtani Fayez	2	0	16
Wang Chia-Nan	10	125	19	Gupta Rajesh	2	0	16
Hosseinzadeh Mehdi	3	13	18	Kakkar Riya	2	0	16

Source: Authors.

Five clusters were identified in the network, and the largest set of connected items in the network consisted of 35 authors (Figure 7): red (Husain Syed Tam, Kao Jui-Chung, Ngoc Nguyen Tran, Nguyen Van Thanh, Nhieu Nhat-Luong, Thi Lan Anh Tran, Van Thanh Nguyen, Viet Tinh Nguyen, Wang Chia-Nan, and Wang Yen-Hui) green (Diue Houng Nguyen, Hong-Anh Pham, Hsu-Hao Lin, Huong Le Thi, Phi-Hung Nguyen, Quynh Mai Do, and Thu-Ha Nguyen), blue (Duc-Thinh Nguyen, Hong-Cham Le, Huong-Thuy Phung, Thi-Giang Nguyen, Thi-Hoai Tran, and Thi-Ly Nguyen), yellow (Le Hong-Cham, Nguyen Duc-Thinh, Nguyen Thi-Giang, Nguyen Thi-Ly, Phung Huong-Thuy, and Tran Thi-Hoai), and lilac (Dang Thanh-Tuan, Lin Ming-Hua, Nguyen Kim-Anh, Nguyen Phi-Hung, Pham Hong-Anh, and Tsai Jung-Fa).

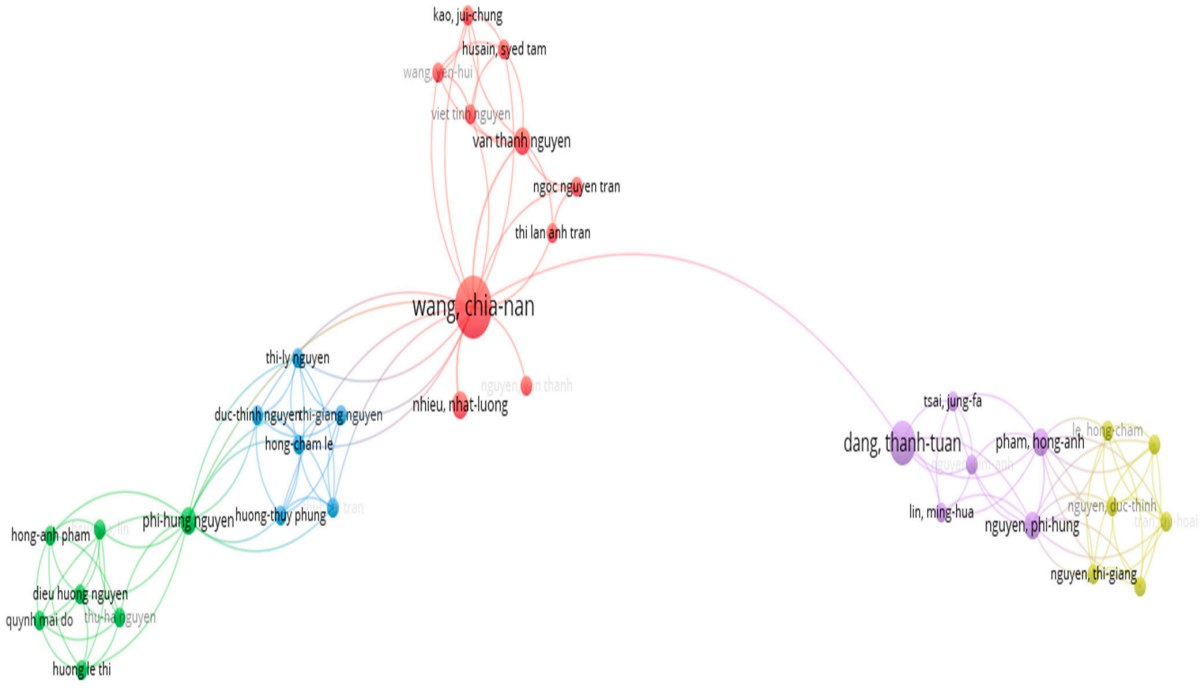

Figure 7. The key collaborative networks among authors (environment*).

Ecologic*

Of the 156 authors, the first 10 with the greatest total link strength are presented in Table 17.

Table 17. The authors with the greatest total link strength (ecologic*).

Author	Documents	Citations	Link Strength	Author	Documents	Citations	Link Strength
Arakelyan Marine	1	7	7	Osipov Fedor	1	7	7
Bobrov Vladimir	1	7	7	Petrosyan Varos	1	7	7
Danielyan Felix	1	7	7	Varshavskiy Alexender	1	7	7
Dergunova Natalia	1	7	7	Ashraf Imran	1	3	6
Omelchenko Andrey	1	7	7	Assad Noureddine	1	3	6

Source: Authors.

The network analysis highlights a single cluster (Figure 8).

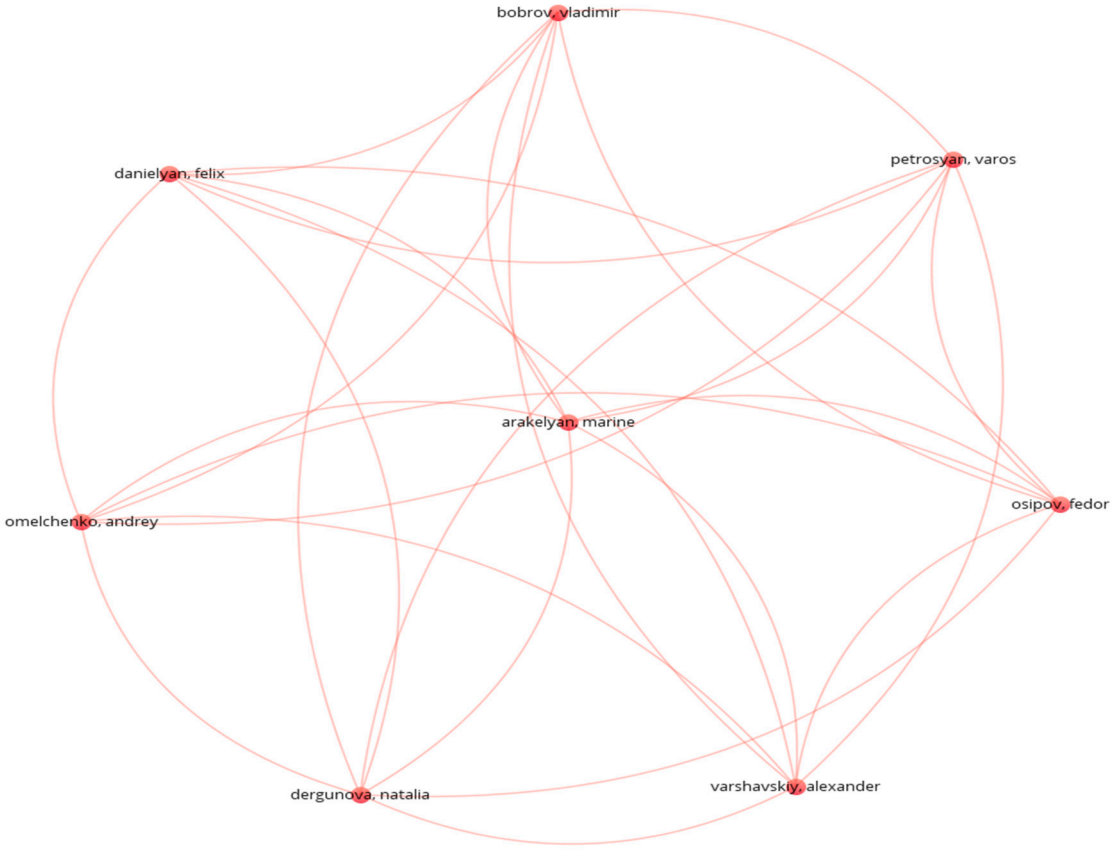

Figure 8. The key collaborative networks among authors (ecologic*).

3.4.2. Co-Authorship—Country

Economic*

Of the 73 countries, the countries with the greatest co-authorship total link strength are presented in Table 18.

Table 18. The countries with the greatest co-authorship link strength (economic*).

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
People's Republic of China	98	406	60	Saudi Arabia	20	74	25
Taiwan	42	209	51	Vietnam	12	159	23
Pakistan	19	86	44	Australia	12	60	22
Russia	58	171	33	France	12	36	22
Spain	93	242	33	Portugal	13	103	22
India	17	82	26	USA	28	100	22
Malaysia	13	87	25				

Source: Authors.

The largest set of connected items in the network consists of 35 items, with six delimited clusters (Figure 9): red (Australia, the Czech Republic, England, Germany, Hungary, the People's Republic of China, Portugal, Slovakia, and Vietnam), green (Canada, Iran, Italy, Malaysia, Romania, Taiwan, Thailand, Turkey, and the USA), blue (Brazil, Egypt, Poland, Russia, Saudi Arabia, Serbia, and South Africa), yellow (Chile, Colombia, Ecuador, Mexico, Spain), lilac (India, Pakistan, and South Korea), and turquoise (France and Greece).

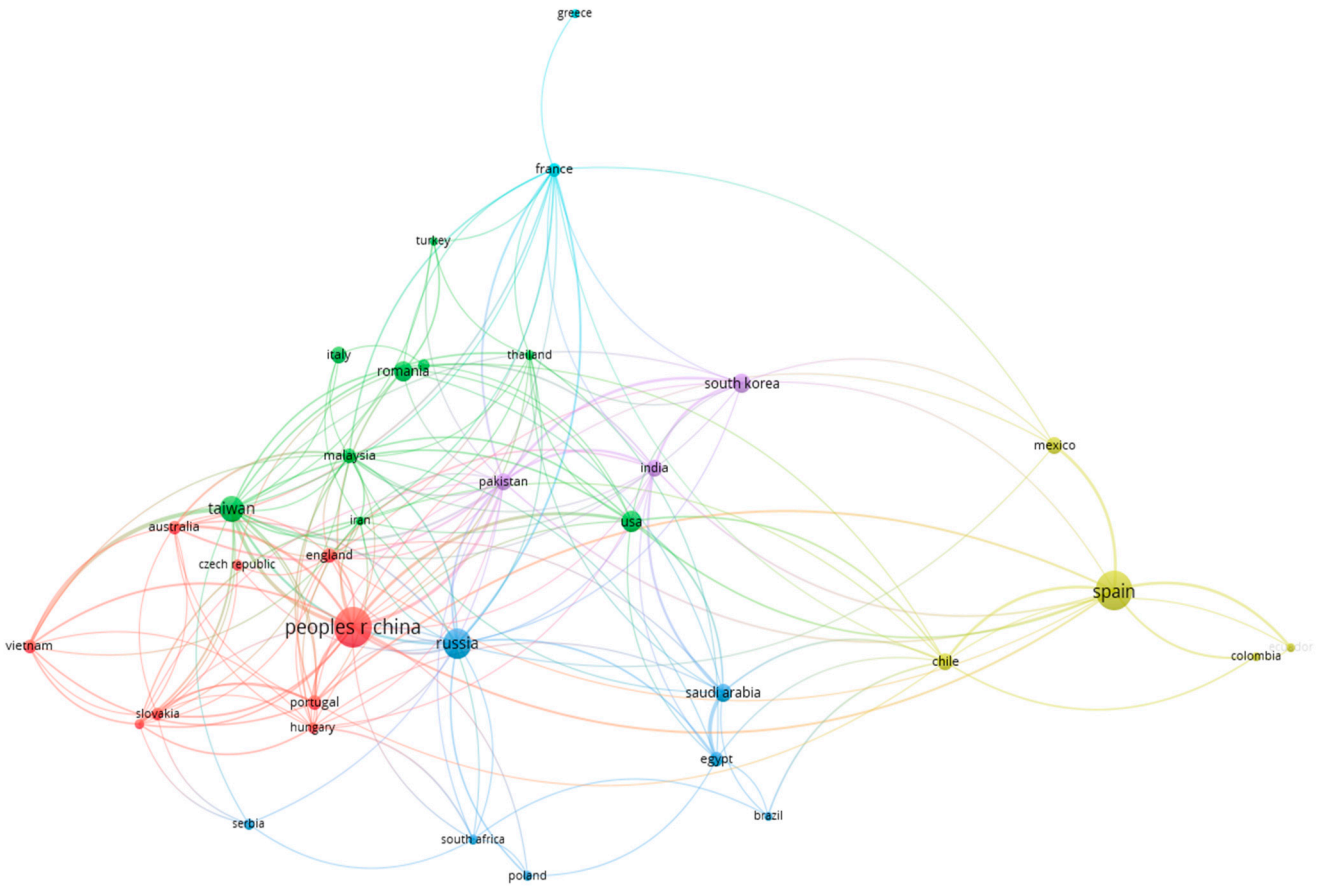

Figure 9. Collaborative network of countries (economic*).

Environment*

Of the 78 countries, the first 10 with the greatest total link strength were selected (Table 19).

Table 19. The countries with the greatest co-authorship link strength (environment*).

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
People's Republic of China	196	959	73	Spain	117	298	54
India	43	256	62	USA	42	176	52
Pakistan	37	287	61	South Korea	59	342	45
Saudi Arabia	44	175	61	Iran	17	128	39
Taiwan	65	323	55	Vietnam	21	195	29

Source: Authors.

The network analysis identifies five clusters. The largest set of connected items consists of 38 countries (Figure 10): red (Chile, Colombia, Germany, Greece, Israel, Italy, Malaysia, Mexico, Nigeria, Portugal, Russia, and Spain), green (Canada, the Czech Republic, France, Iran, Lithuania, Poland, Romania, Serbia, Slovakia, Thailand, Turkey, and Ukraine), blue (Morocco, Pakistan, the People's Republic of China, South Korea, and the USA), yellow (Australia, England, Hungary, Taiwan, and Vietnam), and lilac (Egypt, India, Oman, and Saudi Arabia).

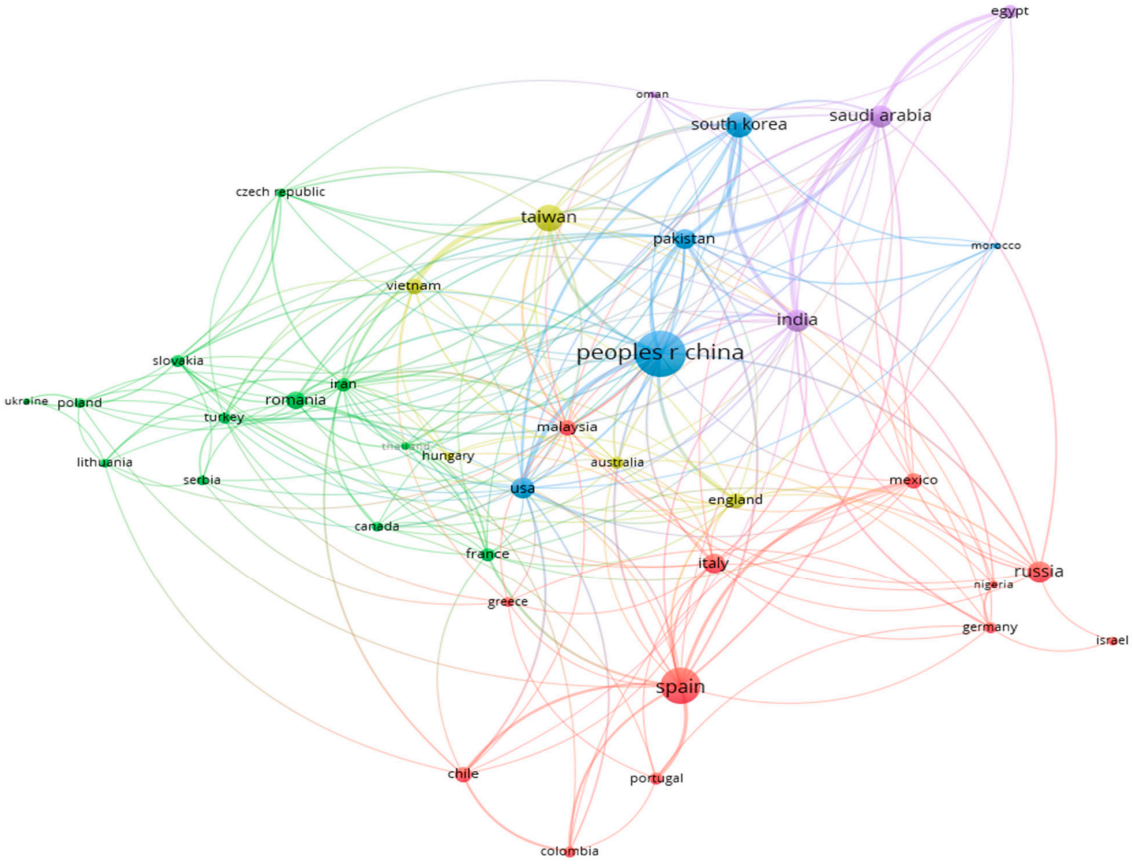

Figure 10. Collaborative network of countries (environmental*).

Ecologic*

Of the 30 countries, 6 meet the threshold (Table 20). The connected countries in the network form three clusters (Figure 11): red (India, Italy, and Spain), green (England and the People's Republic of China), and blue (Russia).

Table 20. The countries with the greatest co-authorship link strength (ecologic*).

Country	Documents	Citations	Total Link Strength	Country	Documents	Citations	Total Link Strength
England	5	6	5	Italy	6	42	2
India	5	19	4	Russia	8	11	2
Spain	9	9	4	People's Republic of China	7	16	1

Source: Authors.

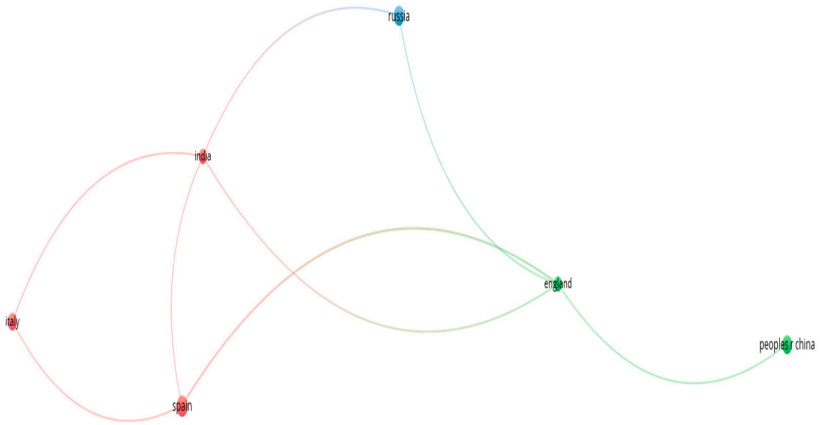

Figure 11. Collaborative network of countries (ecologic*).

3.5. Bibliographic Coupling

The bibliographic coupling reveals the overlap in the reference lists of the scientific publications, constituting a reference to the probability that two papers aimed at a related subject matter. The analysis concerned both the documents and the authors included in the reference lists.

3.5.1. Bibliographic Coupling—Documents

Economic*

The first 10 documents with the greatest total strength links of bibliographic coupling of the 472 are presented in Table 21.

Table 21. The documents with the greatest total strength links of bibliographic coupling (economic*).

Document	Citations	Total Link Strength	Document	Citations	Total Link Strength
Tarasov (2019c)	53	302	Sett (2020)	4	86
Tarasov (2019a)	8	229	Tayyab (2019a)	14	79
Tarasov (2020c)	4	121	Kang (2019)	15	71
Tarasov (2019b)	15	116	Tenreiro Machado (2020a)	6	67
Sarkar (2020)	9	89	Bhuniya (2019)	25	65

Source: Authors.

The largest set of connected items in the network consists of 376 documents, identifying 17 clusters (Figure 12).

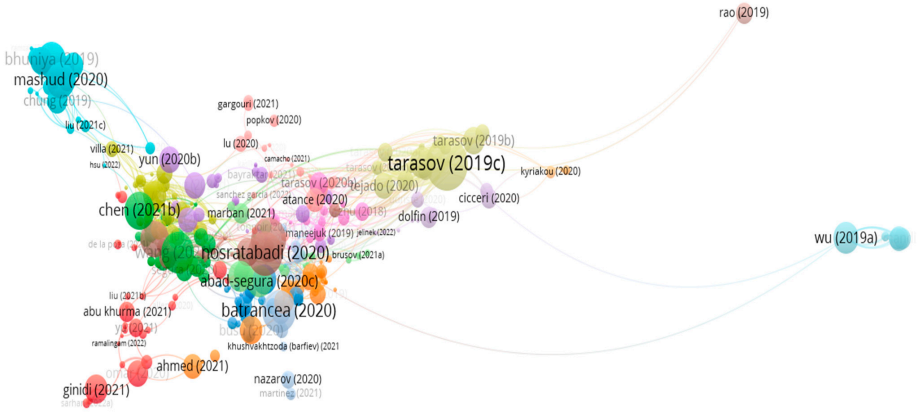

Figure 12. Papers' clustering by coupling (economic*).

Environment*

Of the 738 documents, the first 10 with the greatest total strength links of bibliographic coupling are presented in Table 22.

Table 22. The documents with the greatest total strength links of bibliographic coupling (environmental*).

Document	Citations	Total Link Strength	Document	Citations	Total Link Strength
Tang (2019)	36	204	Wei (2020)	20	181
Sirbiladze (2021)	6	199	Garg (2020)	48	180
Riaz (2022)	3	186	Wang (2020b)	24	178
Zhou (2020)	59	186	Niu (2022)	0	170
Zhang (2019)	55	182	Senel (2020)	4	169

Source: Authors.

The largest set of connected items in the network consists of 563 documents, identifying 20 clusters.

The large number of clusters highlights the existence of a multitude of addressed issues (Figure 13).

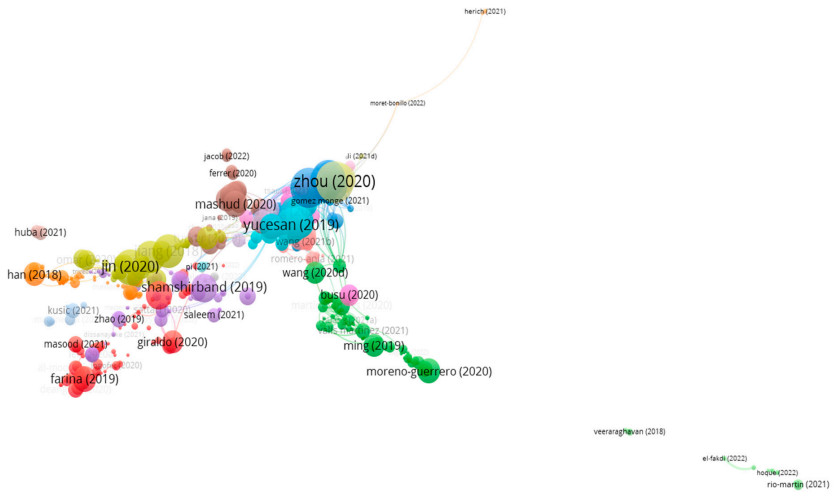

Figure 13. Papers' clustering by coupling (environment*).

Ecologic*

Of the 47 documents, the first 10 with the greatest total strength links of bibliographic coupling are presented in Table 23.

Table 23. The documents with the greatest total strength links of bibliographic coupling (ecologic*).

Document	Citations	Total Link Strength	Document	Citations	Total Link Strength
Abbas (2022)	0	3	Diele (2020)	10	2
Ahmed (2018)	6	3	Zhang (2020)	5	2
Wildi (2018)	4	3	Podani (2018)	5	2
Mondal (2022)	0	2	Pal (2018)	5	2
Oborny (2018)	2	2	Carletti (2019)	0	1

Source: Authors.

The largest set of connected items in the network consists of four documents, identifying two clusters: Sukhinov (2021), Zhang (2020), Ahmed (2018), and Diele (2020).

3.5.2. Bibliographic Coupling—Authors

Economic*

For each of the 1467 authors, the total strength of the bibliographic coupling links with other authors was calculated, and the first 10 authors with the greatest total strength links were selected (Table 24).

Table 24. The authors with the greatest total strength of bibliographic coupling (economic*).

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Sarkar Biswajit	10	105	2960	Puhong Duan	2	75	1685
Wang Chia-Nan	10	87	2578	Abad-Segura Emilio	4	54	1338
Band Shahab S.	2	75	1685	Gonzales-Zamar Mariana-Daniela	4	54	1338
Ghamisi Pedram	2	75	1685	Zhao Xu	4	16	1259
Mosavi Amirhosein	2	75	1685	Alvarez-Garcia Jose	6	6	1219

Source: Authors.

The largest set of connected items in the network consists of 847 items, identifying 52 clusters (Figure 14).

Environment*

For each of the 2495 authors, the total strength of the bibliographic coupling links with other authors was calculated, and the first 10 authors with the greatest total link strength were selected (Table 25).

The largest set of connected items in the network consists of 838 items, identifying 39 clusters (Figure 15).

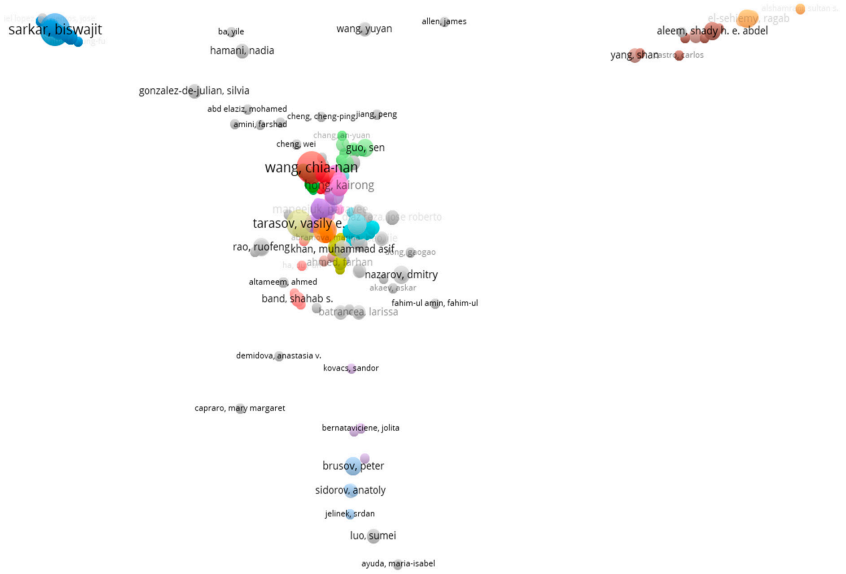

Figure 14. Authors' clustering by coupling (economic*).

Table 25. The authors with the greatest total strength of bibliographic coupling (environment*).

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Wei Guiwu	3	111	2935	Wei Cun	2	91	2012
Garg Harish	4	83	2777	Wei Yu	2	91	2012
Dang Thanh-Tuan	5	67	2632	Nguyen Phi-Hung	2	16	1814
Akram Muhammad	5	37	2428	Pham Hong-Anh	2	16	1814
Wang Chia-Nan	10	125	2238	Ashraf Imran	2	6	1712

Source: Authors.

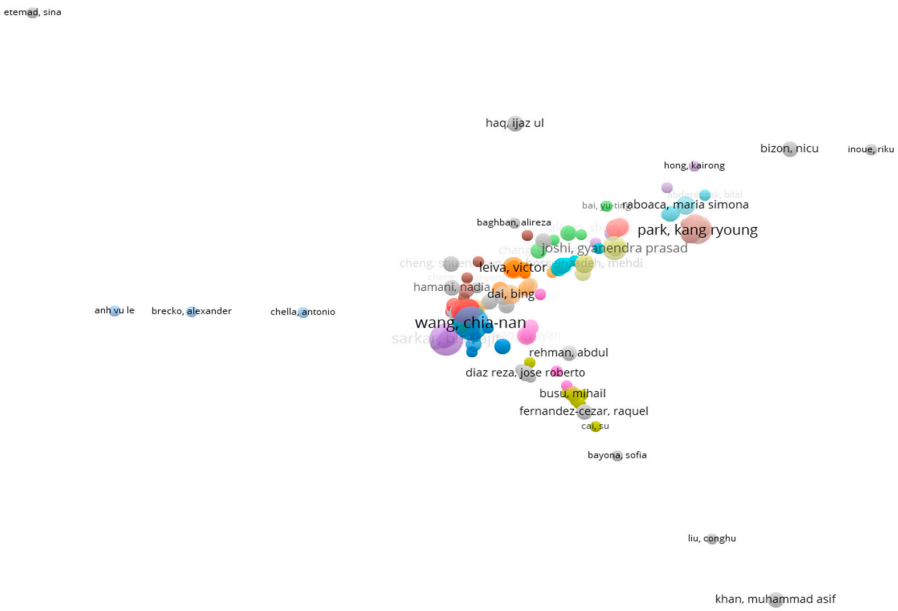

Figure 15. Papers' clustering by coupling (environment*).

Ecologic*

The total strength of the bibliographic coupling links with other authors for each of the 156 authors was calculated. The first ten authors with the greatest total link strength were selected (Table 26).

The largest set of connected items in the network consists of 13 items, identifying 4 clusters: Belova Yulia, Beskopylny Alexey, Chistyakov Alexander, Meskhi Besarion, and Sukhinov Alexander I.; Hu Wen-Si, Liu Quan-Xing, Zhang Kang; Ahmed Danish A., Petrovskii Sergei V., and Tilles Psaulo F.C.; and Diele Fasma and Marangi Carmela.

Table 26. The authors with the greatest total strength of bibliographic coupling (ecologic*).

Author	Documents	Citations	Total Link Strength	Author	Documents	Citations	Total Link Strength
Arakelyan Marine	1	7	1463	Osipov Fedor	1	7	1463
Bobrov Vladimir	1	7	1463	Petrosyan Varos	1	7	1463
Danielyan Felix	1	7	1463	Varshavskiy Alexander	1	7	1463
Dergunova Natalia	1	7	1463	Asraf Imran	1	3	573
Omelchenko Andrey	1	7	1463	Assad Noureddine	1	3	573

Source: Authors.

3.6. Co-Citation

The structure of scientific knowledge is investigated using a co-citation analysis. The co-citation network explored the links between citations in order to detect the relationships between authors and construct a knowledge structure.

Economic*

Of the 17424 authors, 21 met the threshold for a minimum number of 20 citations, and the first 10 authors with the greatest total strength of the co-citation links with other authors were selected (Table 27).

Table 27. The authors with the greatest total strength of the co-citation links with other authors (economic*).

Author	Citations	Total Link Strength	Author	Citations	Total Link Strength
Tarasova V.	74	2395	Sarkar B.	91	276
Tarasov Ve.	108	2360	Cardenas-Barron L.	22	186
Machado J.	28	666	Taleizadeh A.	22	152
Tejado I.	26	599	Saaty T.	33	69
Granger C.	27	544	Zavadskas E.	23	60

Source: Authors.

The visualization of the scientific publications based on the authors' co-citation patterns, considering the largest set of connected items in the network, highlighted three clusters (Figure 16): Charnes A, Diebold FX., Fama EF. Hair JF., Saaty TL., Shaheen AM., Wang CN., Wang Y., Zadeh LA., and Zavadskas E.; Granger CWJ., Machado JAT., Tarasov VE., Tarasova VE., and Tejado I.; Cardenas-Barron LE., Chung KJ., Sarkar B., and Taleizadeh AA., with relevant nodes. An intellectual structure of specific disciplines is created.

Figure 16. Co-citation analysis on authors (economic*).

Environment*

Of the 24,507 authors, 40 meet the threshold for a minimum number of 20 citations. The first ten authors with the greatest total strength of the co-citation links with other authors are presented in Table 28.

Table 28. The authors with the greatest total strength of the co-citation links with other authors (environment*).

Author	Citations	Total Link Strength	Author	Citations	Total Link Strength
Garg H.	101	1413	Xu Z.	64	707
Wei G.	83	1200	Atanassov K.	57	697
Yager R.	84	935	Peng X.	27	481
Zadeh L.	119	850	Ye J.	32	458
Liu P.	69	844	Wang J.	33	363

Source: Authors.

The largest set of connected items in the network consists of 38 items, in 5 clusters (Figure 17): red (Hair JF., Li J., Li X., Liu Y., Mirjalili S., Sarkar B., Taleizadeh AA., Wang J., Wang L., Wang Y., Yang XS., Zhang J., and Zhang Y.), green (Buyukozkan G., Govindan K., Keshavaz Ghorabaee M., Liu HC., Rezaei J., Saaty TL., Salabun W., Wang CN., and Zavadskas EK.), blue (Garg H., Li L., Liu PD., Peng XD., Wei GW., Xu ZS., and Yager RR.), yellow (Akram M., Atanassov KT., Zadeh LA., and Zimmermann HJ.) and lilac (Pramanik S., Smarandache F., Wang H., and Ye J.).

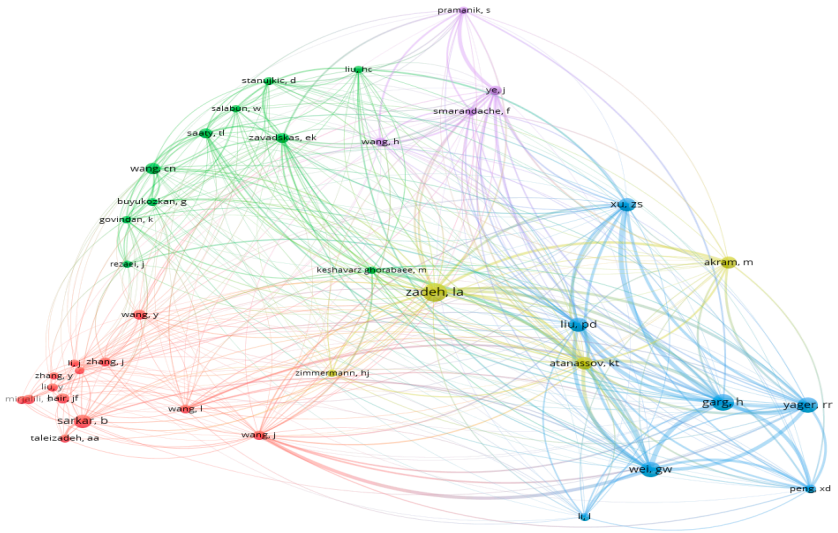

Figure 17. Co-citation analysis on authors (environment*).

Ecologic*
There is no co-citation between the authors of the articles on ecological issues.

4. Conclusions

This paper gives a general overview of the studies published in *Mathematics* (ISSN 2227-7390) by using bibliometric indicators and the Web of Science database (WoS). Only scientific publications related to the use of mathematical tools for the analysis of economic, ecological, and environmental phenomena are considered. The results show that there has been a high increase in the number of research papers published in the mathematics journal during recent years, especially in the economic and environmental fields, and that most of the documents are indexed as articles. The contributions come from all over the world, but the majority are from the People's Republic of China and Spain. All these publications have received the widest attention from the scientific community and contributed to the high rating of the journal.

Wang Chia-Nan (n = 20) and Sarkar Biswajit (n = 19) are the most prolific authors, addressing both economic and environmental issues. They focus on the use of mathematical tools in solving economic and environmental problems, providing relevant benchmarks for decision-makers. The development of approaches by publishing several articles in the field ensures a superior quality of the research and a greater pertinence of the results.

Regarding the meso-topics with the most citations, the results show that the artificial intelligence and machine learning, numerical methods, and statistical methods stand out. In terms of the types of models, data envelopment analysis (DEA) models, Bayesian networks (BNs), decision trees, and dynamic stochastic general equilibrium (DSGE) models were the most used in the selected articles. DEA is a data-oriented approach that converts multiple inputs into multiple outputs. The DEA models were used to evaluate the eco-efficiency of different economies [55,56], to help managers make decisions [57] and to empirically analyze the performance of efficiency in different industries [36,39]. Bayesian networks (BNs), also known as Bayes(ian) models or probabilistic directed acyclic graphical models, enjoy applications to numerous fields, but the focus of the current paper is on fields related to economics, ecology, and environmental applications, such as the optimization of customs fraud control [58], the number of factors that have nowcasting power on GDP [59], and stock price volatility [60]. Applications of BNs can also be found in the behavior of air pollution [61] and the simulation of portfolio decisions under uncertainty [62]. The decision tree is a simple model used to predict the affiliation with a class or an estimate of a numerical target value. It was used to estimate soil temperature [63], to measure and monitor atmospheric ozone concentration levels [64], to develop some decision support systems that can predict natural event propagation [65], and to typologize innovative meso-systems in industry in the context of sustainable development [66]. The dynamic stochastic general equilibrium (DSGE) model adopts the combination of theoretical modeling and stochastic simulation in order to effectively observe the dynamic relationship change among economic variables and accurately measure the expected trend. This model has become the mainstream research method in the field of economic research [67]. Besides the four models, there are other ad-hoc modeling approaches that are designed and used by researchers to conduct economic evaluations in particular circumstances that do not fit in the mainstream modeling paradigms. The application of mathematical models in economic, ecological, and environmental research can help us better understand and use the knowledge in these fields, thus providing strong support for solving practical problems. However, for this, it is important to evaluate how predictions associated with a specific model and data set are expected to be accurate. For selected papers, the most widely used performance evaluation methods were the bootstrap method [68–70]) and the cross-validation method [71–73]. The choice of one method or another depended on the underlying dataset.

The term co-occurrence analysis found a predominant use of mathematical tools in optimization processes in areas with increased volatility, such as the stock market, in order to rigorously substantiate the decisions of investors and policymakers. Furthermore, it

revealed the importance of mathematics, technology, and education in solving environmental problems. The relationships between the citations of the publications have allowed us to establish clusters by key words based on the level of citation. In the communities in which the main keywords were collected, a predominance of terms related to economic, ecological, and environmental issues applied to the different clusters was again observed.

The bibliographic coupling revealed that the documents (Tarasov, 2019c; Tarasov, 2019a; Tang, 2019, etc.) and the authors (Sarkar Biswajit; Wei Guiwu; Garg Harish etc.) had the greatest total strength links of bibliographic coupling. The co-citation network explored the links between citations and detected the authors with the greatest total strength of the co-citation links with other authors (Tarasova V.; Tarasov Ve.; Garg H. etc.).

With reference to the contributions of our research, first of all, this study presents an overview of the main current research in which mathematical models offer possibilities for the analysis of economic, ecological, and environmental phenomena. Secondly, the study highlights the main articles, authors, countries, and networks in this field by reporting to the journal *Mathematics.* Thirdly, the main directions in which mathematical tools can be used appropriately and rigorously for economic, environmental, and ecological research were identified. In this way, our study can effectively contribute to the discovery of new knowledge and the management and use of existing knowledge resources [74].

The span of opportunity for future research is wide. Thus, based on the same data, other kinds of interesting analysis are possible to identify which institutions are supporting and furthering the use of mathematical tools for the analyses of economic, ecological, and environmental phenomena. In this sense, some characteristics of the authors can be taken into account, such as their doctoral granting and employer institutions. This may reveal collaborations across disciplines. Future research could also analyze the editorial position of the mathematics journal over time and identify how journal output matches those editorial positions.

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