Interrelationship Between Trade and Environment: A Bibliometric Analysis of Published Articles from the Last Two Decade

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Abstract

Extant literature indicates that the concepts of international trade and environment are intertwined. As the one aspect, the pollution haven hypothesis (PHH) talks about the effect of trade liberalization on environmental regulation and other aspects, pollution haven effect (PHE) talks about the influence of environmental regulation to trade competitiveness. There is a plethora of theoretical and empirical research studies that explore the relationship between the two concepts. However, to date, no systematic attempts have been made to analyze these publications to understand the current research trends in the trade-environment intersection. Hence, the present study is an attempt to contribute to a deeper understanding of the relationship between trade and the environment through a bibliometric analysis of 1390 research articles collected from the Scopus database from 2000 to 2021. By using performance analysis, conceptual structure analysis, intellectual structure analysis, and bibliographic coupling analysis, the study aims to analyze the current research front and research trends in the trade-environment intersection. The study uses Bibliometrix and VOSViewer software to identify the leading countries, journals, authors, universities, and articles in this domain of research. Further, the science mapping analysis is employed to discover the trending topics in the trade-environment intersection research domain. The results of the study will be useful for researchers to get insights into the research development trends and research themes in the field of trade and environment.

1. Introduction

Bibliometric research is a scientific method of conducting research that analyzes the quantitative data of bibliometric material comprising of books, articles and, other publications (Pritchard, 1969). It is a method to review research papers to identify the current research trends, most cited documents, current research gaps, emerging topics, most commonly used keywords, and so on in a particular research domain. The present study is a bibliometric analysis that explores the intersection between the concepts of international trade and the environment. Thus, the present study aims to explain how these two concepts are being jointly developed by analyzing the recent academic research publications.

The intersection between trade and the environment is an important research area that has attracted the attention of many researchers for decades. The focus of research in this area started in the early 1970s with pioneering works of Baumol (1971), d'Arge and Kneese (1972), Walter (1974), and Pethig (1976). Since then there has been a rapid expansion in research studies related to international trade and the environment. While some of these research works analyze the impact of international trade on environmental policy and pollution emission, others explore the influence of environmental regulation on the trade pattern and the global distribution of production. In this context, it is noteworthy to mention two theories, namely, the pollution haven hypothesis (PHH) and the pollution haven effect (PHE), which have been the basis for several research works in this area. PHH links the environmental regulation stringency to trade liberalization stating that "Trade liberalization causes the dirty sector to expand in countries with weak environmental policies and to contrast in countries with stringent environmental policies" (Duan et

al., 2021a, p.8). Whereas, PHE suggests that the environmental regulation stringency of a country is the source of comparative advantage in pollution-intensive industries (Duan et al. 2021a; Duan, et al., 2021b).

In the 1990s some researchers empirically examined the impact of trade liberalization on the environment in terms of scale effect, technique effect, and composition effect (Grossman and Kruger, 1991; Copeland and Taylor, 1994, 1995). Later, Antweiler et al. (2001) developed a theoretical model that explains the relationship between trade and pollution by considering the interactions of scale, technique, and composition effects. According to the scale effect, there is an increase in economic activities due to trade liberalization which raises pollution. Technique effect refers to the change in the production methods due to trade liberalization (Cole and Elliot, 2003). Finally, the composition effect discussed the effect on pollution due to change in the sectoral composition of clean and dirty industries or due to the changes in the composition of output, both of which in turn, is decided by the comparative advantage and the degree of trade openness of the countries (Cherniwchan et al., 2017). Soon after many other researchers conducted empirical studies to test the PHH theory (Frankel and Rose, 2005; Levinson, 2009; Managi, et al., 2009; McAusland and Millimet, 2013; Cui, et al., 2016; Brunel, 2017; Duan et al., 2021a).

There is a vast number of research works devoted to the empirical testing of PHE, that is, the lenient (strong) environmental policy increases (decreases) trade competitiveness. The PHE theory has been employed in various contexts. Some studies have examined the impact of environmental regulation on foreign direct investment (FDI) location choices (Xing and Kolstad, 2002; Cole and Elliott, 2005; Kellenberg, 2009; Wagner and Timmins, 2009; Reeza, 2013; Erdogan, 2014; Chung, 2014; Tang, 2015; Millimet & Roy, 2016; Cai et al., 2016); others have examined the impact of environmental regulation on the global sourcing choices (Li and Zhou,2017; Berry et al., 2021). Some other studies have explored the relationship between environmental regulation and trade flow (export and import) (Cole and Elliott, 2003; Levinson and Taylor, 2008; Costantini and Mazzanti, 2012; Hering and Poncet, 2014; Chen and Xu, 2021). Still, others have examined the effect of environmental regulations on the global value chain (Zhang et al., 2017; Wang et al., 2018; Duan, et al., 2021b). Studies like Zugravu-Soilita, (2017); Huang et al. (2017); Zhao et al. (2020) examined the impact of environmental regulation on the pollution level of host countries through FDI.

Thus, as more and more researchers publish articles on the relationship between trade and the environment, there is an impending need to explore systematically the evolution of academic research studies on the relationship between these two concepts over time. Bibliometric analysis can help in undertaking such a systematic study on the published articles. To the best of the authors' knowledge, there are no previous bibliometric analysis studies linking trade with the environment.

The present bibliometric study is broadly divided into two parts, performance analysis, and science mapping analysis. The research questions that will be answered through each of these analyses are as follows.

Research questions for performance analysis are:

1. What is the pattern of annual publication trends?
2. Which are the most productive countries?
3. Which are the most trending and impact-full scientific journals?
4. Who are the most relevant authors?
5. Which are the most productive institutions?
6. Which are the most influential articles?
7. What are the most frequently used keywords?

Research questions for science mapping analysis are:

1. What is the conceptual structure of current research on Trade and the environment?
2. What is the intellectual structure (underlying themes) of current research on Trade and environment?
3. What is the current development of themes in the research field?

The rest of the paper is organized as follows. Section 2 describes the methodology used in this study. Section 3 briefly explains the results and discussions of the bibliometric analysis. Section 4 presents the conclusion, limitations, and future research recommendations.

2. Methodology

Subsection 2.1 explains the procedure followed to gather the sample documents. Subsection 2.2 explains the various techniques of bibliometric analysis used in this study to analyze the collected sample documents.

2.1 Data Set Configuration

The present study uses the Scopus database to extract the sample documents. Scopus is a very large dataset that includes a broad range of journals as compared to other databases (Zhang et al. 2020; Casprini et al., 2020; Bretas and Alon, 2021). In this study, a suitable query was created using Boolean Operators in the search field to extract the sample documents. First, to extract all the publications, the present study used the search query ("environment* regulation*" OR "environment* protection*" OR "environment* polic*") and (trade OR export OR import) in the title, abstract, or keyword field. Then the study limited the document type to articles and excluded other types of documents such as book chapters, conference papers, and reviews so that only those published articles that have gone through academic rigor through a systematic review process are considered. Again, the subject area was limited to Economics, Social science, and Business. Further, publications that are only in the English language were considered and the year of publication was limited from 2000 to 2021. Then, the articles with missing information on authors' names, authors’ affiliations, abstracts, reference lists were excluded from the analysis. After following all these steps, the study obtained a sample of 1390 publications up to 12 October 2021. Table 1 describes the search strategy and the process of inclusion and exclusion of the dataset used in this study.

Table 2 gives a brief overview of the information of the bibliometric dataset. A total of 2932 authors contributed and 3533 number of authors appeared in the 1390 research articles published in 324 different journals. The study found 357 single-authored documents with documents per author is 0.474, authors per document are 2.11, and co-authored per document is 2.54. This signifies that a very good number of research articles were published in collaboration with other authors that can also be seen from the collaboration index which is 2.52. Collaboration index is the ratio of the total number of authors from multi-authored articles divided by the total number of multi-authored documents (Koseoglu, 2016a). Also, we can see from Table 2 that 3628 authors' keywords and 4824 keywords plus have appeared in the study. Keywords plus are the words or phrases that appear frequently in the titles of an author's references (not necessarily in the title of the article or author keywords) which are generated by an automatic computer algorithm (Garfield and Sher, 1993).

Table 1

Search strategy and filtering of data

Date	Database	Search String	
12-10-2021	Scopus	TITLE-ABS-KEY ("environment* regulation*" OR "environment* protection*" OR “environment* polic*") AND TITLE-ABS-KEY (trade OR export OR import)	
First-stage filters applied			
Filter First Stage	Document Type: Articles	Language: English	Source Type: Journal
Results	6734 journal articles in English		
Subject area filters from the Scopus categories applied			
Filter the second stage	Scopus Categories: Economics, Econometrics, and Finance; Business, Management, and Accounting		
Result	1648 articles from relevant subject areas		
Year’s filter Applied			
Filter third stage	Years were limited to 2000 to 2021		
Results	1433 articles were selected		
No Information Available filter			
Filter Fourth Stage	The study excluded the articles that did not have information on any of the authors' names, authors’ affiliations, abstracts, and reference lists.		
Results	1390 articles were finally selected for analysis		

Table 2

Main Information About Data

Description	Results
Timespan	2000:2021
Sources (Journals)	324
Documents	1390
Average years from publication	7.91
Average citations per document	27.42
Average citations per year per doc	3.406
References	60326
Article	1390
Keywords Plus (ID)	4824
Author's Keywords (DE)	3638
Authors	2932
Author Appearances	3533
Authors of single-authored documents	328
Authors of multi-authored documents	2604
Single-authored documents	357
Documents per Author	0.474
Authors per Document	2.11
Co-Authors per Documents	2.54
Collaboration Index	2.52

2.2 Bibliometric analysis method

Bibliometric research is a scientific method of conducting research that helps to analyze the quantitative data of bibliometric material comprising of books, articles and, other publications (Pritchard, 1969). Bibliometric methods can be broadly divided into two types, namely, performance analysis and bibliometric mapping or science mapping (Piñeiro-Chousa et al., 2020; Baier-Fuentes et al., 2019). The performance analysis helps to evaluate the scientific impact of publication, authors, journal, organization, country, etc. which is based on the number of publications and their citations. Other metrics can also be used such as h-index (Hirsch,2005), impact factors, and cite scores. The performance analysis used in the present study is applied to countries, sources, authors, institutions, documents, organizations, and keywords. “The mapping of Science attempts to find representations of intellectual connections within the dynamically changing system of scientific knowledge” (Small, 1997, P. 275). Different methods can

be applied in scientific mappings such as co-citation, bibliographic coupling, co-occurrence of keywords, and co-authorship methods. Co-citation analysis analyzes the frequency of two documents being cited together by other documents (Small, 1973). Bibliographic coupling is based on citing documents and it occurs when a document is commonly cited by two documents (Kessler, 1963). Cooccurrence of keywords means the most common keyword used in all documents and their common occurrence in each paper (Callon et al., 1983). Finally, the co-authorship measures the degree of collaboration or co-authorship among the most productive sources (Baier-Fuentes et al., 2019; Peters and van Raan., 1991). The present study used co-citation analysis, bibliographic coupling, and co-occurrence of keywords for scientific mapping.

To perform bibliometric analysis, the study used the Bibliometrix package in the R and VOSViewer software (Van Eck & Waltman, 2010) version 1.6.16. The Bibliometrix package is “an open-source tool for executing a comprehensive science mapping analysis of scientific literature” (Aria and Cuccurullo, 2017). VOSviewer helps to display the large bibliometric map which can be easily interpreted (Aria and Cuccurullo, 2017). Each software allows one to do network analysis in both visual and tabular formats.

3. Results And Discussion

In this section, the study presents the results of performance analysis and bibliometric analysis. From sections 3.1. to 3.7, the study will answer the research questions 1 to 7, respectively. Sections 3.8, 3.9. and 3.10. will answer research questions 8, 9, and 10, respectively.

3.1 Publications by Year

Fig.1 presents the trend in the number of articles published in the combined research area of trade and environment. The first paper in this area was published by Pethig (1976), where the author tested hypotheses based on Neo-classical Trade Theory for pollution generating industries in different countries. However, since the focus of the present bibliometric study is the last two decades, the scope of articles is limited to those published from 2000 to October 2021. As is visible in Fig.1, overall, there is an increasing trend in the number of publications during the period of analysis. The highest numbers of articles (107 articles) were published in 2019 and 2020 followed by 100 articles in 2018. The lowest number of published articles during the study period (25 articles) was in 2004. In the year 2021, up to 12 October 2021, 97 articles were published in this area of research. Thus, the trade-environment intersection area of research is even now an increasingly sought-after topic in the academic research arena.

3.2 Publications by Countries

Table 3 shows the top 20 publishing countries in terms of affiliation of corresponding author’s country on the trade-environment research theme. Each of these 20 countries published a minimum of 13 articles. Top publishing countries are the USA, China, United Kingdom, Germany, and Australia with each country contributing more than 50 articles. In terms of total citations, the USA again ranked first with 8400 citations followed by the United Kingdom with 3577 citations and China with 3093 citations. However, in

terms of average citations per document, Hong Kong is ranked first with 63.46 average citations followed by Sweden (40.18) and the Netherlands (39.10). From table 3, it can be seen that only China and India are the developing countries that are featured in the top 20 publishing countries in terms of the number of publications in the trade-environment intersection area of research.

Table 3

Top 20 Publishing Countries

Country	No. of Publications	Total Citations	Average Citations Per Article
USA	259	8400	32.43
CHINA	162	3093	19.09
UNITED KINGDOM	95	3577	37.65
GERMANY	74	1959	26.47
AUSTRALIA	57	1827	32.05
CANADA	49	1372	28.00
JAPAN	44	1046	23.77
FRANCE	41	766	18.68
ITALY	35	1315	37.57
SPAIN	34	1252	36.82
NORWAY	30	584	19.47
NETHERLANDS	29	1134	39.10
SWITZERLAND	26	858	33.00
SWEDEN	22	884	40.18
INDIA	21	485	23.10
KOREA	18	426	23.67
AUSTRIA	16	547	34.19
FINLAND	15	221	14.73
HONG KONG	13	825	63.46
DENMARK	13	346	26.62

3.3 Most frequent Journals

A total of 1390 articles appeared in 324 journals. Fig. 2 lists the top 20 journals based on the highest number of articles on the trade-environment concept. The top publishing journals are Journal of Cleaner Production with 133 publications followed by Environmental and Resource Economics with 115 and Ecological Economics with 112 publications. Table 4 shows the most impact-full journals based on the total citations, h-index, m-index, and g-index. h-index is the Journal's number of published articles(h) each of which is cited in other papers h times. m-index is the ratio of h-index divided by the number of years since the first paper was published in the journal. g-index is the (unique) largest number such that the top g articles received (together) at least g^2 citations. Based on the three indices and total citations, the top and the impactful sources are Journal of Cleaner Production, Environmental and Resource Economics, Ecological Economics, Energy Economics, and Journal of Environmental Economics and Management. According to Bradford's law (Bradford, 1934; Hjørland and Nicolaisen, 2005), these five journals are the core journals as they together account for 1/3rd of the total publications in the trade and environment research theme (Fig. 3).

Table 4

Most Impact-full Journals

Sources	Total Citations	Number of Articles	h-index	g-index	m-index	Year of First Article
JOURNAL OF CLEANER PRODUCTION	4599	126	35	62	1.59	2000
ENVIRONMENTAL AND RESOURCE ECONOMICS	2064	111	25	40	1.14	2000
ECOLOGICAL ECONOMICS	5707	106	38	74	1.73	2000
ENERGY ECONOMICS	2844	76	31	51	1.41	2000
JOURNAL OF ENVIRONMENTAL ECONOMICS AND MANAGEMENT	3768	75	34	60	1.70	2002
RESOURCES, CONSERVATION AND RECYCLING	1862	54	22	42	1.05	2001
RESOURCE AND ENERGY ECONOMICS	548	27	12	23	0.57	2001
INTERNATIONAL ENVIRONMENTAL AGREEMENTS: POLITICS, LAW AND ECONOMICS	295	26	10	16	0.67	2007
WORLD ECONOMY	514	26	12	22	0.55	2000
TECHNOLOGICAL FORECASTING AND SOCIAL CHANGE	1038	20	15	20	0.88	2005
BUSINESS STRATEGY AND THE ENVIRONMENT	843	19	14	19	0.67	2001
ENVIRONMENT AND DEVELOPMENT ECONOMICS	484	16	9	16	0.41	2000
JOURNAL OF WORLD TRADE	104	15	6	9	0.33	2004
RESOURCES POLICY	417	14	10	14	0.45	2000
AUSTRALIAN JOURNAL OF AGRICULTURAL AND RESOURCE ECONOMICS	227	13	9	13	0.41	2000
MARINE POLICY	262	13	8	13	0.62	2009
WORLD DEVELOPMENT	278	13	11	13	0.52	2001
ECONOMIC MODELLING	264	12	7	12	0.32	2000
FOREST POLICY AND ECONOMICS	156	12	7	12	0.78	2013
ENVIRONMENTAL ECONOMICS AND POLICY STUDIES	72	11	5	8	0.23	2000

3.4 Most Relevant Authors

Productivity and impact are two of the important criteria to evaluate the relevance of an author in a particular research field. The productivity of an author can be measured by the number of articles produced in a given period and impact can be evaluated by the total number of citations received in each year (Forliano et al., 2021). Fig. 4 presents the most relevant authors list with both these measures. In the figure, the line represents the authors' timeline, bubble size is proportional to the number of documents, and darkness of bubbles is proportional to total citations. It can be noted that Chen Y (10), Cole MA (8), and Liu Y (8) are the most productive authors during the timeline. Further, Cole MA (509 in 2003), Elliott RJR (386 in 2003), and Lai K-H (350 in 2012) received the highest number of citations in a year.

To know the most relevant authors, some studies advocate computation of author-based measures including h-index, m-index along with total citation (TC), and the number of publications (NP) (Bretas and Alon, 2021; Forliano, et al., 2021). Table 5 presents the top 20 productive authors based on these four measures. The most cited authors in the list are Cole MA (921), Elliott RJR (593), and Lai K-H (506). Cole MA is also the best combination of productivity and impact, as the author has 8 publications and an h-index of 8 (each article received a minimum 8 number of citations). This author is followed by Rutherford TF with 7 publications and an h-index of 7 and Chen Y with 6 publications and an h-index of 6. The m-index is used to avoid penalizing the younger scholars who have just started publishing in this area. m-index is defined as the h-index weighted for the activity period of an author (Hirsch, 2007). Wang Y and Nassani AA are the most recent productive authors in this area and both started publishing in 2018. Their respective m-indices are 1.25 and 0.75.

Table 5

Most productive authors based on h-index

Element	h-index	m-index	TC[a]	NP[b]	PY_start[c]
COLE MA	8	0.421	924	8	2003
BÖHRINGER C	6	0.462	278	7	2009
LIU Y	5	0.5	145	7	2012
RUTHERFORD TF	7	0.538	360	7	2009
WANG Y	5	1.25	118	7	2018
CHEN Y	6	0.462	105	6	2009
ELLIOTT RJR	5	0.263	596	6	2003
FREDRIKSSON PG	5	0.25	306	6	2002
HUANG Y	4	0.4	86	6	2012
LAI Y-B	5	0.278	55	6	2004
GREAKER M	5	0.263	132	5	2003
HAMDI-CHERIF M	4	0.571	199	5	2015
LAI K-H	5	0.455	507	5	2011
LI J	4	0.235	45	5	2005
LI Y	3	0.375	62	5	2014
LI Z	3	0.333	102	5	2013
MCAUSLAND C	5	0.25	142	5	2002
NASSANI AA	3	0.75	83	5	2018
REILLY JM	5	0.385	168	5	2009
WANG S	5	0.294	112	5	2005

a=total citations, b= number of publications, c= year of the first published paper

3.5 Most Productive Institutions

Table 6 describes the top 20 affiliated institutes of authors based on their number of publications. In total 1269 institutes were involved in the publications of articles in the trade-environment research theme. Among the top 20 research institutes, 6 were from China, and 5 were from the USA. One interesting finding is that both these countries are also leading ones in terms of the highest number of articles (Table 2). However, although Germany, Canada, Japan, France, Italy, and Spain featured in the top 10 publishing countries, none of the institutes from these countries are in the list of top 20 most productive institutes.

The University of California has the highest number of publications with 33 publications. This is followed by Tsinghua University with 22 articles and Peking University with 17 articles.

Table 6

Most Productive Institutions

Affiliations	Country	Articles
UNIVERSITY OF CALIFORNIA	USA	33
TSINGHUA UNIVERSITY	China	22
PEKING UNIVERSITY	China	17
KING SAUD UNIVERSITY	Saudi Arabia	16
UNIVERSITY OF BIRMINGHAM	UK	16
WAGENINGEN UNIVERSITY	Netherlands	16
LUND UNIVERSITY	Sweden	14
RENMIN UNIVERSITY OF CHINA	China	14
THE HONG KONG POLYTECHNIC UNIVERSITY	Hong Kong	14
MASSACHUSETTS INSTITUTE OF TECHNOLOGY	USA	13
TIANJIN UNIVERSITY	China	13
UNIVERSITY OF MARYLAND	USA	13
NORTHEASTERN UNIVERSITY	USA	12
POTSDAM INSTITUTE FOR CLIMATE IMPACT RESEARCH	Germany	12
UNIVERSITY OF MANCHESTER	UK	12
AUSTRALIAN NATIONAL UNIVERSITY	Australia	11
FINNISH ENVIRONMENT INSTITUTE	Finland	11
NORTH CHINA ELECTRIC POWER UNIVERSITY	China	11
SICHUAN UNIVERSITY	China	11
STANFORD UNIVERSITY	USA	11

3.6 Citations Analysis

The number of citations received by a document is considered to be one of the most suitable measures to identify the most influential articles in the current research front (Merigo et al., 2015). Citation analysis enables the establishment of intellectual linkages by using citations and references of the published

articles (Appio et al., 2014). Table 7 represents the top 20 research publications by the global citations (GC), where GC means the number of citations received by the documents from the entire database including works in other research areas and disciplines. Local citations (LC) are the number of citations received by the documents within the collected database only (in this study citation received from 1390 documents). In Table 7, the average number of global citations received each year (GC/Y) and normalized global citations are also shown. In the present study, Christmann and Taylor (2001) received the most GCs (657) followed by Zhu and Sarkis (2006) with 598 GCs and Tanner and Kast (2003) with 528 GCs. The leading articles in terms of LCs are Levinson and Taylor (2008) with 48 LCs followed by Cole and Elliott (2003) with 24 LCs and Managi et al. (2009) with 22 LCs. The top three articles in terms of the highest LCs focused on the relationship between environment and international trade. While the first two articles focused on PHH/PHE, Managi et al. (2009) worked on the theme of trade openness and environment quality. In terms of GC/Y and normalized total citations, Wu and Pagell (2011) ranked first followed by Zhu and Sarkis (2006) and Christmann and Taylor (2001). While the first two articles were concerned with green or sustainable supply chain management, the study by Christmann and Taylor (2001) focused on the positive environmental effects of globalization.

Table 7

Top 20 most relevant documents in the dataset ordered by the global citations received (GC)

Authors	Title	Journal	Year	GC[a]	LC[b]	GC/Y[c]	Normalized GC
Christmann and Taylor	Globalization and the environment: determinants of firm self-regulation in China	Journal of international business studies	2001	657	10	31.29	14.13
Zhu and Sarkis	An inter-sectoral comparison of green supply chain management in China: drivers and practices	Journal of cleaner production	2006	598	3	37.38	12.58
Tanner and Kast	Promoting sustainable consumption: determinants of green purchases by Swiss consumers	Psychology and marketing	2003	528	0	27.79	8.32
Wu and Pagell	Balancing priorities: decision-making in sustainable supply chain management	Journal of operations management	2011	483	2	43.91	13.20
Levinson and Taylor	Unmasking the pollution haven effect	International economic review	2008	391	48	27.93	9.15
Cole and Elliott	Determining the trade-environment composition effect: the role of capital, labor, and environmental regulations	Journal of environmental economics and management	2003	387	24	20.37	6.10
Druckman and Jackson	The carbon footprint of UK households 1990-2004: a socio-economically disaggregated, quasi-multi-regional input-output model	Ecological economics	2009	380	2	29.23	8.70
Carter et al.	Environmental purchasing and firm performance: an empirical investigation	Transportation research part e: logistics and transportation review	2000	364	3	16.55	8.17
Cederberg and Mattsson	Life cycle assessment of milk production - a comparison of	Journal of cleaner production	2000	363	0	16.50	8.15

	conventional and organic farming						
Weber and Matthews	Quantifying the global and distributional aspects of American household carbon footprint	Ecological economics	2008	361	3	25.79	8.45
Beise and Rennings	Lead markets and regulation: a framework for analyzing the international diffusion of environmental innovations	Ecological economics	2005	307	4	18.06	6.47
Rehfeld et al.	Integrated product policy and environmental product innovations: an empirical analysis	Ecological economics	2007	295	3	19.67	7.02
Xing and Kolstad	Do lax environmental regulations attract foreign investment?	Environmental and resource economics	2002	283	18	14.15	7.33
Lai and Wong	Green logistics management and performance: some empirical evidence from Chinese manufacturing exporters	Omega	2012	274	3	27.40	7.37
Tukker et al.	Exiopol - development and illustrative analyses of a detailed global mr ee sut/iot	Economic systems research	2013	251	0	27.89	9.55
Managi et al.	Does trade openness improve environmental quality?	Journal of environmental economics and management	2009	247	22	19.00	5.65
Wiedmann et al.	Quo Vadis Mrio? Methodological, data and institutional requirements for multi-region input-output analysis	Ecological economics	2011	235	2	21.36	6.42
Oltra and	Sectoral systems of	Technological	2009	227	1	17.46	5.19

Saint Jean	environmental innovation: an application to the French automotive industry	forecasting and social change					
Damania et al.	Trade liberalization, corruption, and environmental policy formation: theory and evidence	Journal of environmental economics and management	2003	221	19	11.63	3.48
Carlson et al.	Sulfur dioxide control by electric utilities: what are the gains from trade?	Journal of political economy	2000	216	6	9.82	4.85

a= global citations, b= local citations, c= global citations/year

3.7 Keyword Analysis

The frequency of occurrence and relevance of keyword plus and author keywords are analyzed here. Table 8 represents the top 20 most frequently occurring keywords plus and authors keywords. Among the keywords used in the search query for this study, “Environmental Policy” is the most frequently occurring keyword in both keywords plus and author's keywords list. Among keywords other than those used in the search query, the frequently occurring keywords include climate change, China, sustainable development, emissions trading, and Carbon dioxide (CO_2 emission) in the top 20 lists of keywords plus and authors keywords. Fig. 5 (A) and Fig. 5 (B) depict the word cloud of the top 50 keywords plus and authors keywords, respectively. The top two keywords were not shown in the word clouds because they consist of the set of terms used to build up the query. Word cloud/tag cloud helps to quickly identify the most prominent words in the literature and the importance of each word is shown in the font size or color/shade of the words. In both these figures, one can see that emission control, China, commerce, climate policy, sustainability, carbon emission, carbon leakage, environmental Kuznets curve, pollution haven hypothesis are the most blooming keywords suggesting that these keywords occurred most frequently.

Table 8

Most Frequent Keywords

Keywords Plus	No. of articles	Authors Keywords	No. of articles
Environmental policy	564	Environmental policy	114
Environmental protection	345	Environmental regulation	81
Environmental economics	279	Climate policy	68
International trade	241	International trade	66
Emission control	206	China	62
Commerce	191	Climate change	58
Climate change	161	Environment	54
Environmental regulations	154	Trade	54
Trade-environment relations	152	Carbon leakage	35
Sustainable development	149	Sustainable development	32
Emissions trading	138	Sustainability	31
Carbon emission	132	Emissions trading	30
Carbon dioxide	130	Cap-and-trade	29
China	124	Environmental regulations	27
Economic and social effects	118	Pollution	20
Environmental impact	108	Co2 emissions	19
United states	102	Foreign direct investment	19
Trade-off	100	Uncertainty	19
Carbon	98	Pollution haven hypothesis	17
Economics	96	Cap and trade	16

3.8 Conceptual structure

The conceptual structure represents the relationship among concepts and words in a set of publications. This structure embodies themes based on the connection between the keywords (De la Hoz-Correa et al., 2018). The conceptual structure can be explained with the help of the co-occurrence network and the thematic evolution of keywords. Co-occurrence networks link the keywords that occur simultaneously in an article, thereby indicating that a relationship exists between the concepts. Thematic map or evolution analyzes the evolution of the topic over time.

In this study, the co-occurrences were identified between the author's keywords, as they are more comprehensive in representing an articles' content in comparison to other types of keywords (Zhang et al.

2016). By following the Louvain cluster algorithm (Blondel et al., 2008), the study detected 50 most developed keywords that were connected, which is represented in Fig. 6. In the figure, the words with higher identified co-occurrences word will appear in the center. The proportion of bubbles represents the occurrence of the keywords in the dataset. The links or the edge size is proportional to item co-occurrence. Each color defines a cluster. In the present study, there are five clusters. They are,

1. Red Bubbles: environmental policy, international trade, sustainability, porter hypothesis
2. Blue Bubbles: environmental regulation, China, air pollution, environmental protection
3. Green Bubbles: climate policy, climate change, carbon leakage, emissions trading
4. Purple Bubbles: environment, sustainable development, pollution
5. Yellow Bubbles: co2 emissions, foreign direct investment, pollution haven hypothesis, environmental Kuznets curve

The study presented a thematic evolution of the topic in different periods in Fig. 7 to get more comprehensive information about the sub-topic. Notably, co-occurrence of top 250 high-frequency author's keywords was considered and two cut-off points were identified by the software tool as 2011 and 2017. As a result, the strategic diagrams for three consecutive sub-periods, 2000-2011, 2012-2017, and 2018-2021 were produced, which is shown in Fig. 7. The first slice contains the topic of 11 years, whereas the second slice contains the topic of 6 years and the third slice is only 4 years because very limited papers are published in the early years and abundant articles are published in recent years (Fig. 7). Thematic maps are very helpful to the researchers to examine the evolution of themes in the four different quadrants (Cobo et al., 2011), identified based on their centrality (plotted on the X-axis) and density (plotted on the Y-axis). Centrality measures the extent to which a theme is connected to other themes in the domain and the relevance of the theme in the overall development of a particular domain. Density measures the extent to which the keywords in a given cluster are internally connected and measures the development of the specific research theme. In the thematic map, the upper right quadrant contains the motor theme, which means high centrality (significance) and high density (well developed). The lower-left quadrant represents low centrality and low density that means the emerging or the declining theme or topic. The upper-left quadrant with low centrality and high density shows highly developed and isolated or specialized themes and, the lower-right quadrant shows basic and transversal themes.

As it is clear from Fig. 7 (A), (B), and (C), the majority of the themes in the present study are located in the top-right and bottom-right quadrants. This implies that the topics are highly significant (high centrality) and either highly developed (high density) or low developed (low density) for the development of the trade-environment intersection research domain. Studies related to environmental regulations, carbon leakage, climate policy, international trade, and cap-and-trade that were in the lower-right quadrant with low density and high centrality in the first period have moved to high density and high centrality quadrant in the second period. However, in the latest period again these topics have moved to low density and high centrality quadrant. This implies that these themes developed during the second time period and have

now become general or basic themes for various studies in the overall research domain. Topics such as environmental protection, economic growth, air pollution, international environmental agreements, and CO2 emission were remain in the low density and high centrality quadrants. That means they are highly significant to the overall research domain but are not that much developed. Thus, there is scope for researchers to pursue future work on these topics. The topic of sustainability started as an emerging topic in the first two periods and is now the most influential and highly developed topic. On the whole, it can be seen that the time horizons of the periods have decreased but the number of topics has increased, signifying the growing richness and diversity of work in the intersection of trade and environment research front.

3.9 Intellectual Structure

The intellectual structure of science mapping helps to analyze how an author's work impacts a given scientific community. It represents the relationship between the cited references in the database by using a co-citation network to capture the intellectual structure (Small, 1973). Co-citation analysis helps to identify clusters of papers that share similar content (Elango, 2019). As, it is useful to know the structure, directions, and development of the research areas (Liu et al., 2015). Co-citation analysis analyzes the frequency of two documents being cited together by other documents (Small, 1973). Here, the unit of analysis is cited references that are cited by the documents of the collected dataset and the co-citation strength between two references will be more if they receive more citations from the documents.

The co-citation network of references for the present study is shown in Fig. 8. The size of the nodes represents the number of citations received by the references in the dataset and the thickness of the edge (the line between the nodes) is in proportion to the strength of co-citation. As shown in Fig. 8, the co-citation network resulted in 4 different clusters in four different colors. Betweenness centrality (Freeman, 1978) of a node plays an important role in the network analysis, as the higher the betweenness centrality of a node higher will be the importance of the article (Koseoglu, 2016b; Huang et al., 2021; Kang et al., 2021). It is defined as the shortest path between nodes that passes through a particular node and the node having higher betweenness scores control all the information and play the role of gatekeeper and broker in the network analysis (Wang et al., 2016; Freeman, 1978). Cluster-1 (Red) comprises 22 contributions, spanning from 1990 to 2012. In this cluster, the article by Copeland and Taylor (2004) plays an important role with a betweenness centrality value of 161.17, followed by Antweiler et al. (2001) with a centrality value of 82.91 and Levinson and Taylor (2008) with a centrality value of 31.74. Cluster-1 identified articles that use pollution haven hypotheses and environmental Kuznets curve to explain the relationship between trade and environment. For example, Copeland and Taylor (2004) theoretically and empirically examined the relationship between international trade, economic growth, and the environment. Antweiler et al. (2001) investigated how the openness of international trade in the goods market affects pollution concentration. Levinson and Taylor (2008) theoretically and empirically examined the effect of environmental regulations on trade flows by applying the pollution haven hypothesis. Cluster-2 (Blue) comprises 17 documents, ranging from 1960 to 2005. Based on centrality, the top three most important articles are Babiker (2005) (centrality value of 54.78), Barrett (1994)

(centrality value of 39.29), and Markusen (1975) (centrality value of 38.55). Cluster-2 mainly focuses on the relationship between environmental policies (climate change policy, carbon tax, international environmental agreements) and international trade. Cluster-3 (Green) comprises 6 documents where the most prominent articles were Copeland (1994) (centrality value of 385.78) and Baumol (1988) (centrality value of 102.11). This cluster focused on the linkage between environmental regulation and international competitiveness (Jaffe, 1995) and the use of international trade theory in environmental concepts (Pethig, 1976). The article Copeland (1994) that takes a pivotal role in this cluster describes how different types of policy reforms in tax regimes and quota regimes make a trade and pollution distortion in a small open economy. Cluster-4 (Violet) comprises of 3 contributions which includes Davis (2010) (centrality value of 4.42), Peters (2008) (centrality value of 2.37) and Peters 2011 (centrality value of 2.31). This cluster mainly focuses on how international trade (export and import) plays a significant role in explaining carbon emission.

3.10 Bibliographic Coupling Analysis

To understand the current development of themes in the research field, the present study performed the bibliographic coupling analysis of documents. Bibliographic coupling is a scientific technique that will indicate when two publications share common references, and hence almost the same content (Kessler, 1963; Weinberg, 1974). This helps the researchers to know the current developmental structures in the research field. In the present study, for a better understanding and analysis, only the document that has at least 20 citations in Scopus and a total link strength of 3 or more are considered. Thus, by following these criteria, 447 articles got selected from the total sample of 1390 articles. Again, among the 447 articles, only 378 articles had a total link strength of 3 or more. By performing bibliographic coupling of these 378 articles in VOSViewer, the study got 6579 links with 11748 total link strength. Here, the links show the number of common references cited in the two documents, and the total link strength is the total number of commonly cited references among one document with all other linked documents.

Through this bibliographic coupling analysis, the study identified 6 clusters and each color represents a cluster (Fig. 9). In Fig. 9, documents having high similarity are placed closer to each other, and which have low similarity are placed far from each other. The size of the bubble is in proportion to the number of total citations. Table 9 summarizes the results of the bibliographic coupling analysis obtained from the VOSViewer software.

Cluster1: Emission Trading and Abatement Cost

Cluster 1 is the largest among all the six-cluster consisting of 132 articles with 7091 citations and 53.72 average citations per article. A total of 331 authors contributed to this cluster with 31 single-authored articles. This cluster mainly focuses on emission trading and abatement cost (Carlson et al., 2000; Carbone et al., 2009; Goulder et al., 2010; Aichele and Felbermayr, 2012; Kriegler, et al., 2015). Energy Economics and Ecological Economics are the important journals in this cluster, each of which published 27 and 21 articles respectively.

The most highly cited article in this cluster is Carlson et al. (2000) which examined the performance of the sulfur dioxide allowance market. That is, the process and the amount of allowance trading that helps to reduce the abatement cost of controlling SO2. The next highly cited work is Tacconi (2012), which redefined and identified the key elements of payment for environmental services from both environmental economics and ecological economics perspective. Another highly cited article in this cluster is by Sims (2010) that provided empirical evidence on the socioeconomic impacts of protected areas in Thailand.

Cluster2: Environmental performance and green supply chain management

Cluster 2 comprises 68 articles with 6838 total citations and 100.53 average citations per article (which is the highest amongst all other clusters). A total of 165 authors contributed to this cluster with 9 single-authored articles. The cluster mostly focused on environmental performance (Christmann and Taylor, 2001; Delmas and Blass, 2010; Carrión-Flores and Innes, 2010) and green supply chain management (Carter et al., 2000; Zhu and Sarkis, 2006; Wu and Pagell, 2011). The leading journals in this cluster were Journal of Cleaner Production, and Business Strategy and the Environment, each of which published 10 articles related to the theme of the cluster.

The most cited article is Christmann and Taylor (2001) that examined the effect of globalization on the self-regulating environmental performance of Chinese firms. This is followed by Zhu and Sarkis (2006) that examined the drivers and practices of green supply chain management in three manufacturing sectors of China and compared the results among them. The third most cited article in this cluster is Wu and Pagell (2011) where the focus was on how companies handle their environmental issues under the green supply chain management decision process.

Cluster3: Environmental Kuznets Curve and Composition Effect

Cluster 3 consists of 52 documents with 4339 total citations and 83.44 average citations per article. A total of 122 authors contributed to this cluster with 11 single-authored articles. The most important journals in this cluster are the Journal of Cleaner Production and Ecological Economics, each of which provided 12 and 8 articles, respectively. The environmental Kuznets curve (Cole, 2003; Esty and Porter, 2005; Culas, 2007; Managi et al., 2009; He and Wang., 2012) and composition effect (Cole and Elliott, 2003; Managi et al., 2009; Shahbaz et al., 2019) are the central themes in this cluster.

Cole and Elliott (2003) is the most cited article in this cluster, where the authors analyzed the determinants of composition effect of trade liberalization on the environment by focusing on differences in capital-labor endowments and differences in environmental regulations. This is followed by the study Managi et al. (2009) that examined the impact of trade openness and income on environmental emission, and Sadorsky (2012) that empirically examined the dynamic relationship between energy consumption, trade (export and import), and output in seven South American countries.

Cluster4: Carbon Footprints and Multi-regional input-output model

Cluster 4 consists of 50 contributions from 167 authors with 4 single authors articles. The cluster received 3957 total citations and 79.14 average citations per article. The leitmotif of this cluster is concerned with carbon footprints (Druckman and Jackson, 2009; Weber and Matthews, 2008; Jakhar, 2015) and the use of a multi-regional input-output model (Druckman and Jackson, 2009; Wiedmann et al., 2011; Qi et al., 2014). Again, the Journal of Cleaner Production is the most important journal in this cluster which published 18 articles followed by Ecological Economics which published 13 articles.

The most-cited article in this cluster is Druckman and Jackson (2009), which examined the various attributes of CO2 emission (carbon footprints) from the different segments of society of UK households and the study is based on a quasi-multi-regional input-output model. In their analysis, they consider both the consumption perspective and production perspective of CO2 emissions. The next important studies in this cluster are Weber and Matthews (2008) that analyzed the importance of globalization (international trade) and distributional aspects in estimating US household carbon footprints, and Wiedmann et al. (2011) that summarized the current state of development, methodological implication, and the future option of multi-regional input-output analysis (MRIO).

Cluster5: Pollution Havens

Cluster 5 contains 44 articles, which have been cited 2974 times with 67.59 average citations per article. A total of 96 authors contributed to this cluster with 7 single-authored documents. The main journals included in this cluster are the Journal of Environmental Economics and Management (14) and Ecological Economics (6). Authors in this cluster mostly focused on the pollution haven hypothesis and effect (Levinson and Taylor, 2008; Zeng and Zhao, 2009; Mulatu et al., 2010; Manderson and Kneller, 2012; Rezza, 2013; Chung, 2014).

The most highly cited article in the cluster is Levinson and Taylor (2008), in which the authors have tested the pollution haven effect by empirically examining the effect of pollution abatement cost on trade flows (net import). This is followed by Ederington et al. (2005), which proposed three reasons for the failure of previous empirical testing of pollution haven effect and empirically tested the results. The third important study is Zeng and Zhao (2009) that tested the pollution haven hypothesis by considering industrial agglomeration and manufacturing pollution on agricultural productivity.

Cluster6: Trade Liberalization and Environmental Policy

Cluster6 comprises only 32 articles (least among all the clusters) and obtained 1928 citations with 60.25 average citations per article. Interestingly, in this cluster, there are 14 single-authored articles. and On the whole, 45 authors contributed to this cluster. Journal of Environmental Economics and Management (11) and, Environmental and Resource Economics (6) are the major sources of publication in this cluster. Articles in this cluster focused on the concept of trade liberalization and environmental policy (Tanguay, 2001; Damania et al., 2003; Burguet and Sempere, 2003; Cole, 2006).

The most highly cited article in this cluster is Xing and Kolstad (2002), which empirically examined the impact of environmental policy on the foreign direct investment of both high polluting industries and low polluting industries. The study found that there is a significant impact of host countries' laxity of environmental regulation on FDI for high polluting industries and insignificant for low polluting industries. This is followed by Damania et al. (2003), which focused on the intersection between trade liberalization, environmental policy determination, and corruption, and Cole (2006) that explored the relationship between trade liberalization and energy use.

Table 9

Overview of Bibliographic Coupling

Cluster No.	Cluster Color	Number of Paper	TLS*	Top Sources	TC*	Main Topic
1	Red	132	3813	Energy Economics (27) Ecological Economics (21)	7091	Emission Trading and Abatement Cost
2	Green	68	3873	Journal of Cleaner Production (10) Business Strategy and the Environment (10)	6836	Environmental performance and green supply chain management
3	Blue	52	5320	Journal of Cleaner Production (12) Ecological Economics (8)	4339	Environmental Kuznets Curve
4	Yellow	50	1885	Journal of Cleaner Production (18) Ecological Economics (13)	3957	Carbon Footprints and Multi-regional input-output model
5	Purple	44	5928	Journal of Environmental Economics and Management (14) Ecological Economics (6)	2974	Pollution Havens
6	Aqua	32	2716	Journal of Environmental Economics and Management (11) Environmental and Resource Economics (6)	1928	Trade Liberalization and Environmental Policy

*TLS=Total Link Strength

*TC=Total Citations

4. Conclusion

This study provides a bibliometric analysis of articles on the trade-environment intersection based on the Scopus database from 2000 to 2021. The present study uses different bibliographic techniques, namely, performance analysis, conceptual structure analysis, intellectual structure analysis, and bibliographic coupling analysis. The study covered 1390 research articles which are contributed by 2932 authors and co-authors affiliated with 1269 institutions in 61 countries and published in 324 different journals with 38117 total citations during the study period.

The results show that, overall, the academic research articles published in the trade-environment intersection research area are showing an increasing trend with the highest number of papers published in the last two years (2019 and 2020). The USA is leading in terms of both, numbers of publications and total citations. This is followed by China in terms of publications and the UK in terms of total citations. Journal of Cleaner Production, Environmental and Resource Economics, Ecological Economics, Energy Economics, and Journal of Environmental Economics and Management are the most influencing and impact-full journals which are publishing the highest number of papers and also receiving the highest number of citations.

Chen Y is the most productive author having the highest number of publications, followed by Cole MA and Liu Y. However, overall, Cole MA has received the highest number of citations followed by Elliott RJR and Lai K-H. If one considers multiple of the matrices, namely, the number of publications, total citation, and h-index, then Cole MA is the most relevant author in this area. Each of Cole MA's articles directly talks about the relationship between international trade and environmental factors including the role of environmental regulation and capital-labor endowment in determining trade-environment composition effect (Cole and Elliott, 2003), and the impact of trade liberalization on energy use by focusing on scale, technique, and composition effect (Cole, 2006). The most productive institutions are the University of California, Tsinghua University, and Peking University. Most of the productive institutes are from China and the USA, which is reflected even in the high number of publications from these institutions.

The most influential articles according to the global citations are Christmann and Taylor (2001), Zhu and Sarkis (2006), and Tanner and Kast (2003). However, according to the local citations, Levinson and Taylor (2008) is the leading article followed by the articles by Cole and Elliott (2003) and Managi et al. (2009). Thus, the most influential articles as per global citations are different from those based on local citations. This is because the high locally cited articles are focused on the niche area of the trade-environment research domain, whereas the high globally cited articles are focused on green production and consumption in general. Apart from the basic keyword that the study used for the search query, the most frequently occurring author's keywords and keywords plus are climate change, China, sustainable development, emissions trading, Carbon dioxide, environmental Kuznets curve, and pollution haven hypothesis.

In the conceptual structure analysis, the study performed co-occurrence network analysis and thematic evolution of the author's keywords. From co-occurrence network analysis, the study found five different clusters with environmental policy, environmental regulation, climate policy, trade, and CO2 emission are the measure keyword of each respective five clusters. The thematic evolution of the author's keyword resulted in three-time periods with highly significant themes that were either low developed or highly developed. Thus, researchers can work further on the themes such as climate change, carbon leakage, climate policy, environmental protection, air pollution, international environmental agreements, economic growth, and CO2 emission because they are highly influencing, yet not fully developed.

In the intellectual structure of science mapping analysis, the study performed the co-citation analysis of references which resulted in four clusters. Overall, the science mapping analysis revealed the broad underlining themes to be consisting of pollution haven hypotheses, environmental Kuznets curve, environmental policies, international trade, environmental regulation, international competitiveness, carbon emission. Further, the most important cited references in this research area based on betweenness centrality are Copeland B.R. (1994), Copeland (2004), Baumol W.J. (1988), Antweiler et al. (2001), Babiker M.H. (2005), Barrett S. (1994), Levinson and Taylor (2008), and Markusen J.R. (1975).

Bibliographic coupling of research articles has resulted in 6 clusters. These clusters represent the themes of (i) emission trading and abatement cost (ii) environmental performance and green supply chain management (iii) environmental Kuznets Curve and composition effect (iv) carbon footprints and multi-regional input-output model (v) Pollution Havens (vi) trade liberalization and environmental policy. These themes represent the current development in the trade-environment interaction research area and future studies can be conducted in these research areas.

The present study has some limitations that can be overcome in future studies. One of the limitations is that the study uses only the Scopus database. In the future, the study can be extended to include Web of Science and other similar databases. The second limitation is that the study is limited to only published journal articles. Future studies can extend the scope to include other document sources such as book chapters and review papers. Further, a systematic literature review can be conducted to complement the bibliometric study to identify clear research gaps in the literature.

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Consent to Participate:

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Consent to Publish

Not applicable

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Mr. Lakshmana Padhan had the idea about the article who performed the literature search, data collection, and data analysis. Dr. Savita Bhat critically revised the research work.

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Figures

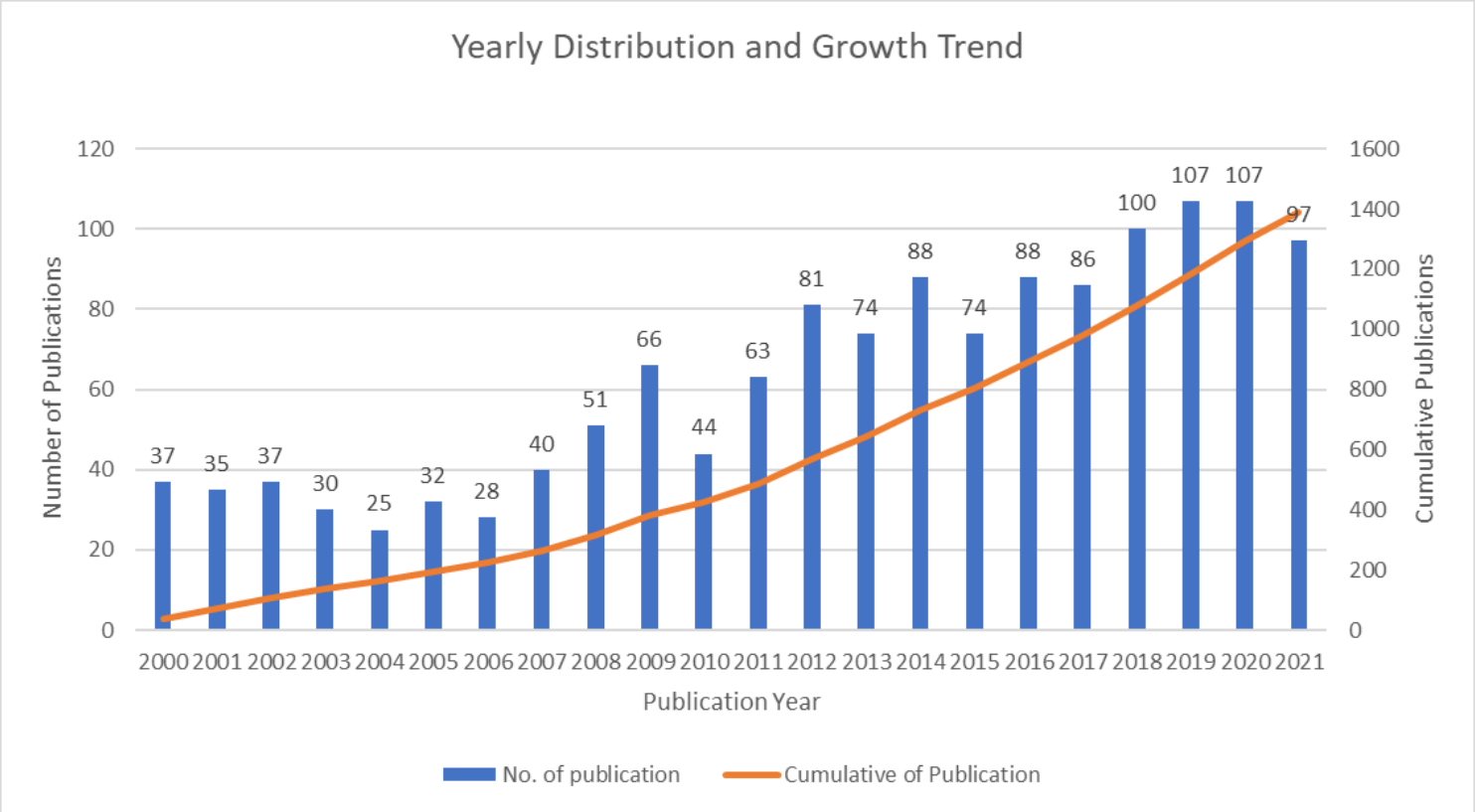

Figure 1

Annual distribution of articles taken from Scopus between 2000 to October 2021.

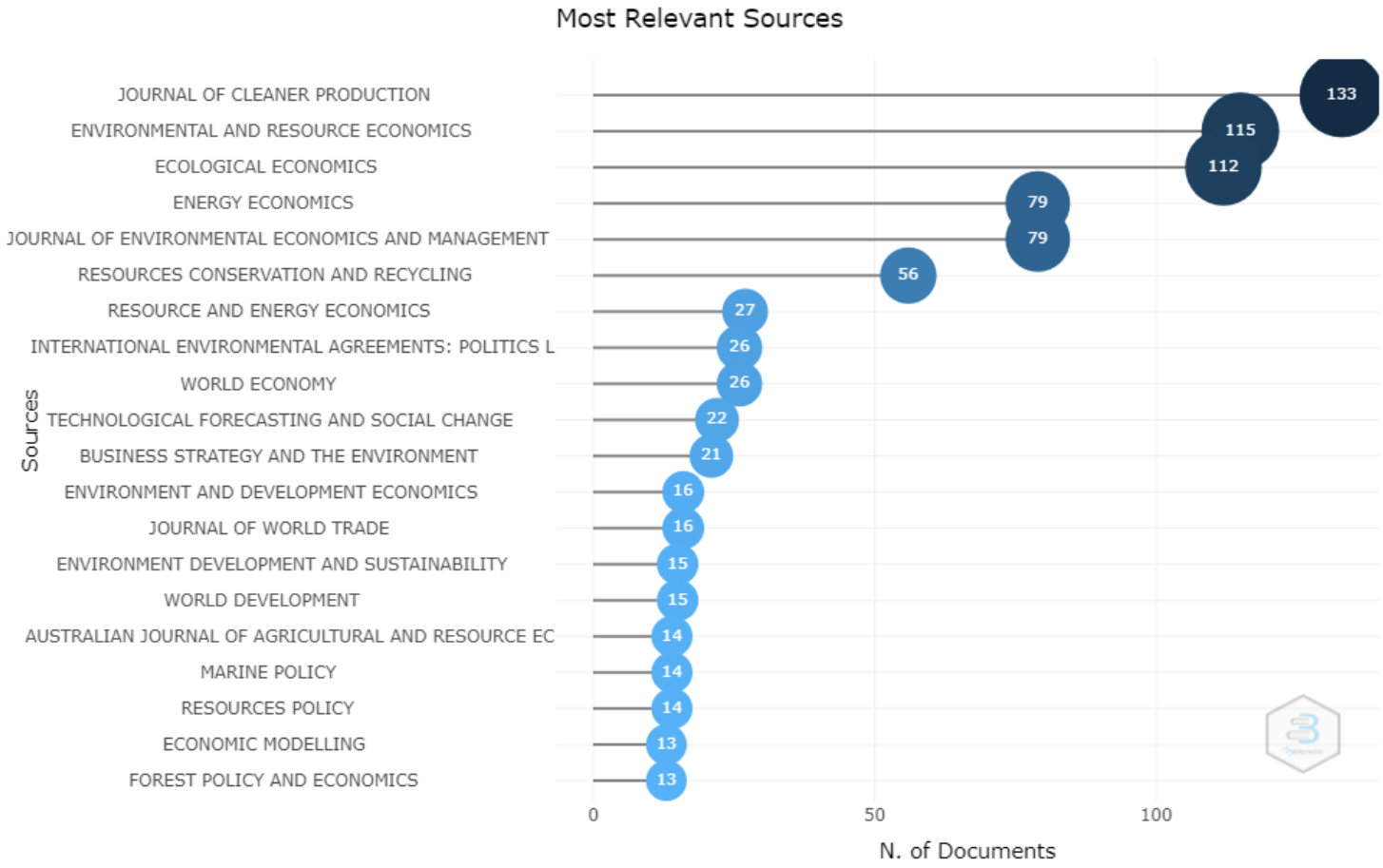

Figure 2

Top publishing Journal (Source: Bibliometrix, based on the Scopus dataset)

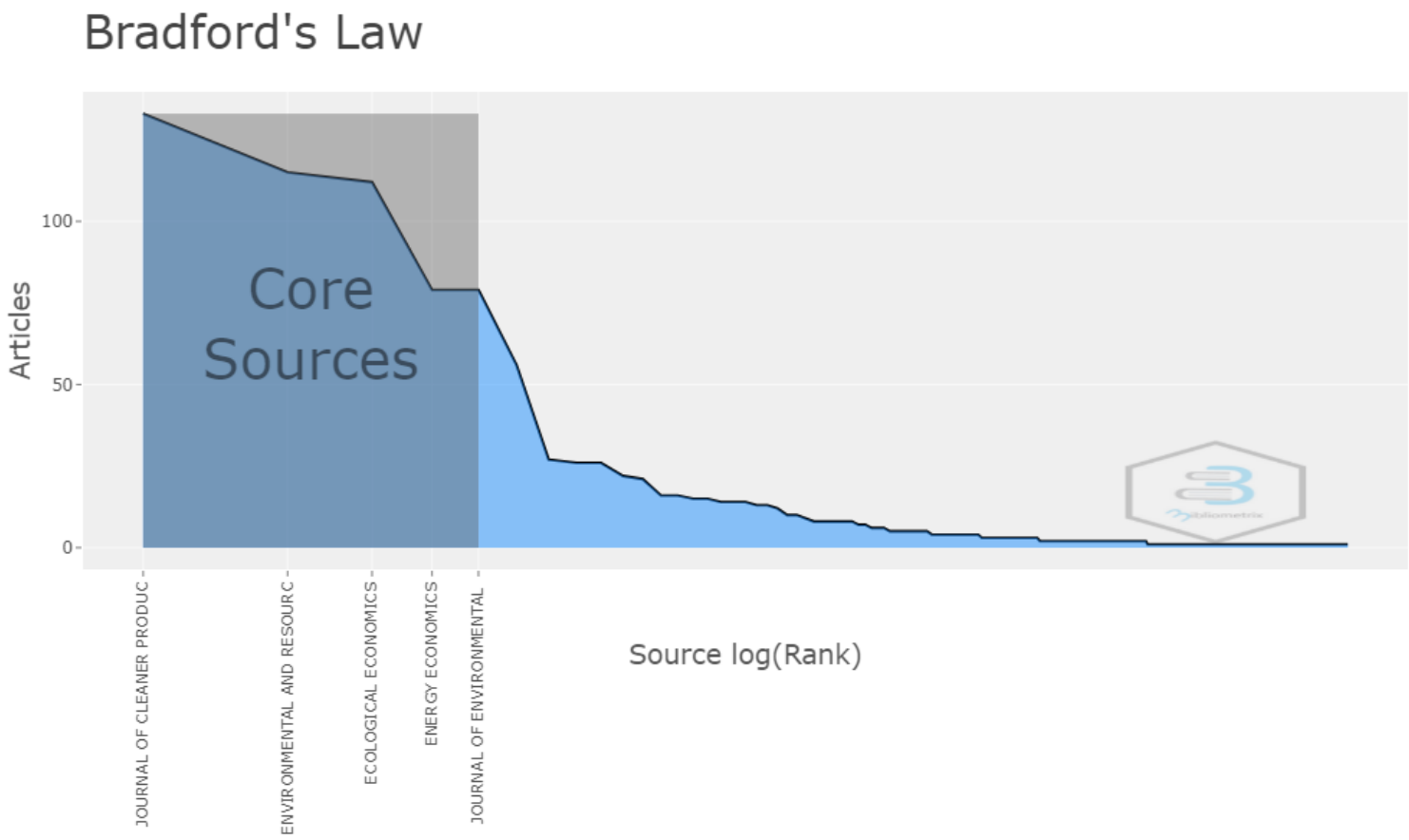

Figure 3

Core Sources (Bibliometrix, based on the Scopus dataset)

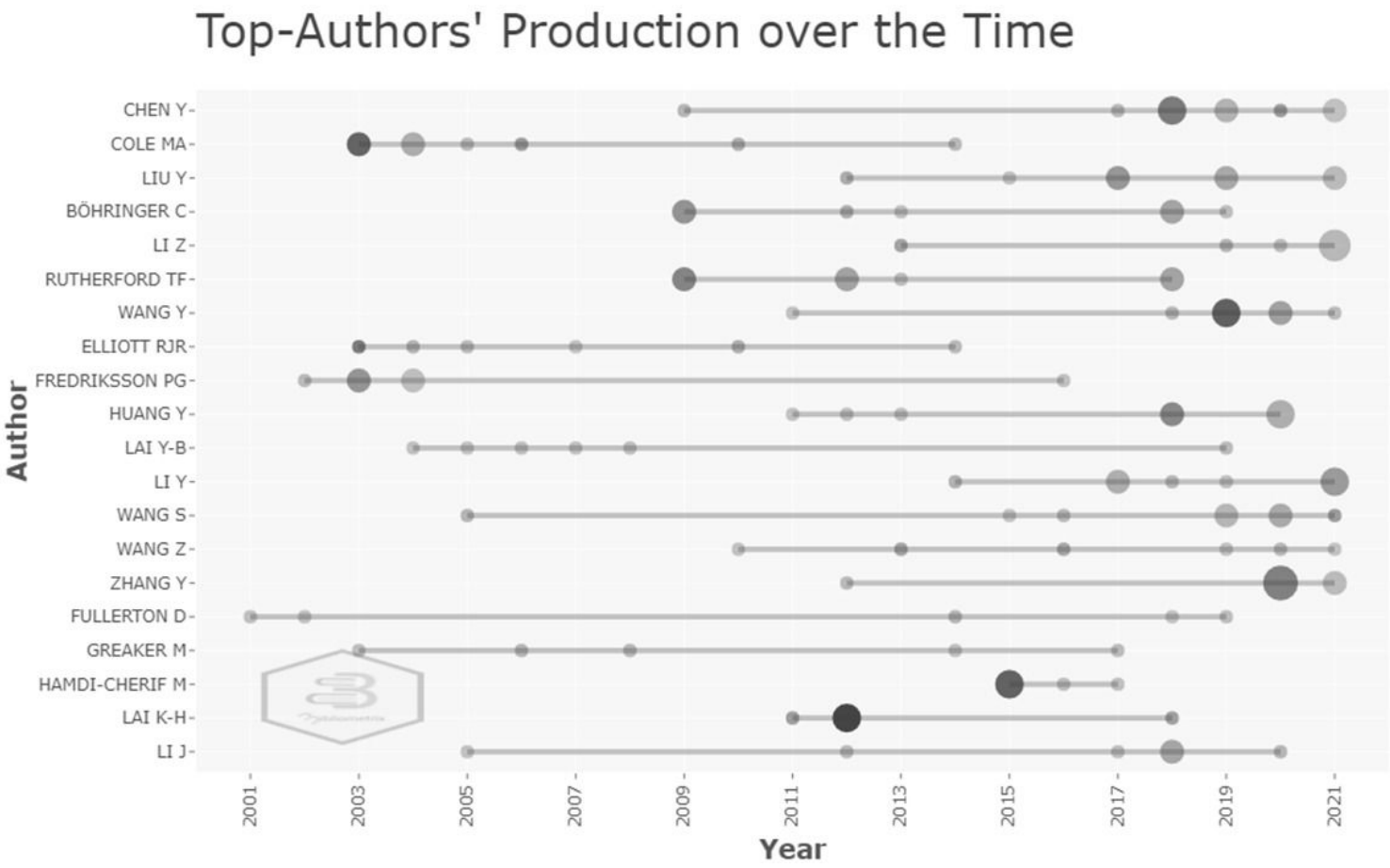

Figure 4

Top authors' production over time (Source: Bibliometrix, based on the Scopus dataset)

Figure 5

(A). Word Cloud of Keyword Plus

(B). Word Cloud of authors Keywords

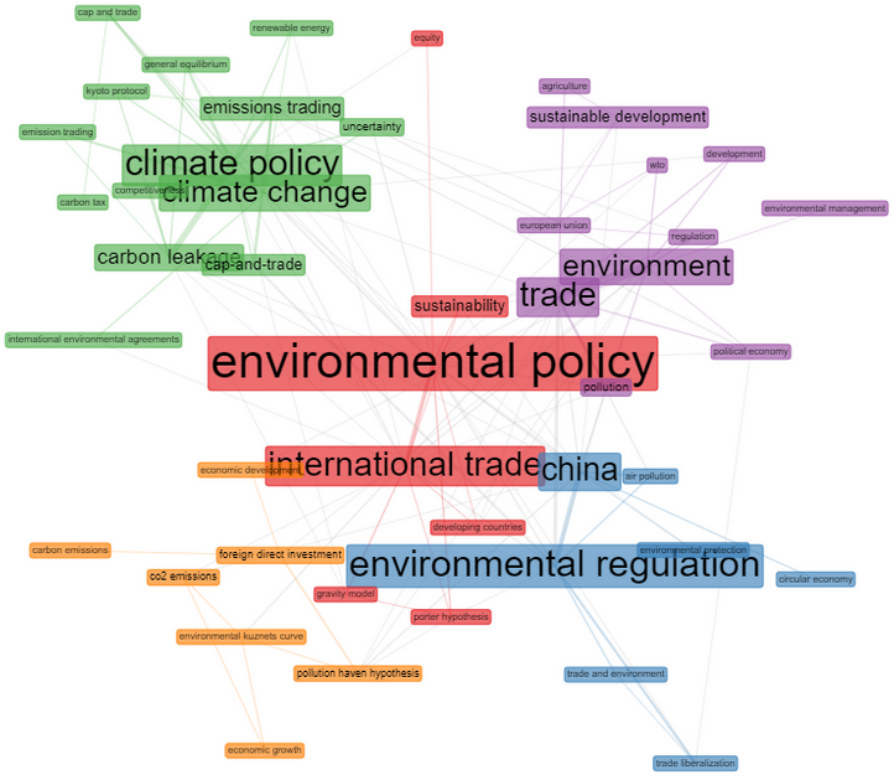

Figure 6

Conceptual Structure of the dataset

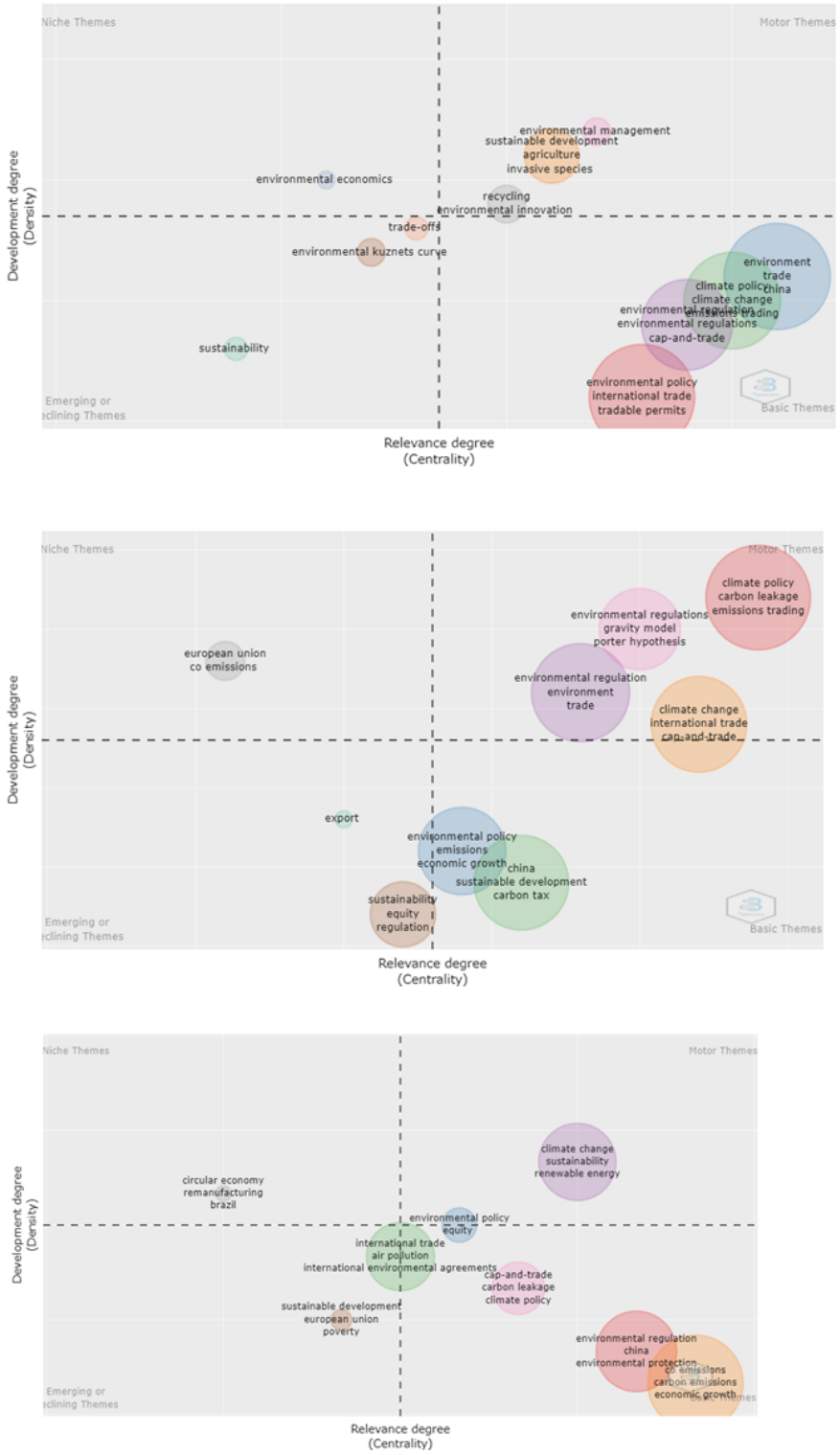

Figure 7

(A) First Time Slice (2000-2011)

(B) Second Time Slice (2012-2017)

(C) Third Time Slice (2018-2021)

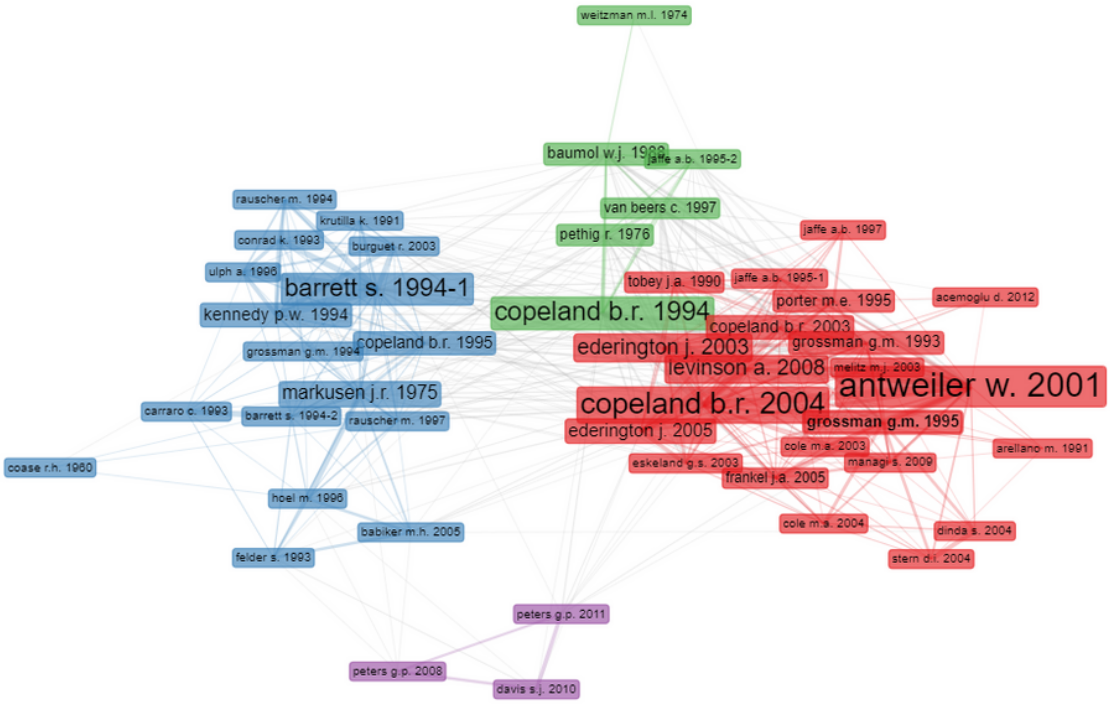

Figure 8

Co-citation Network

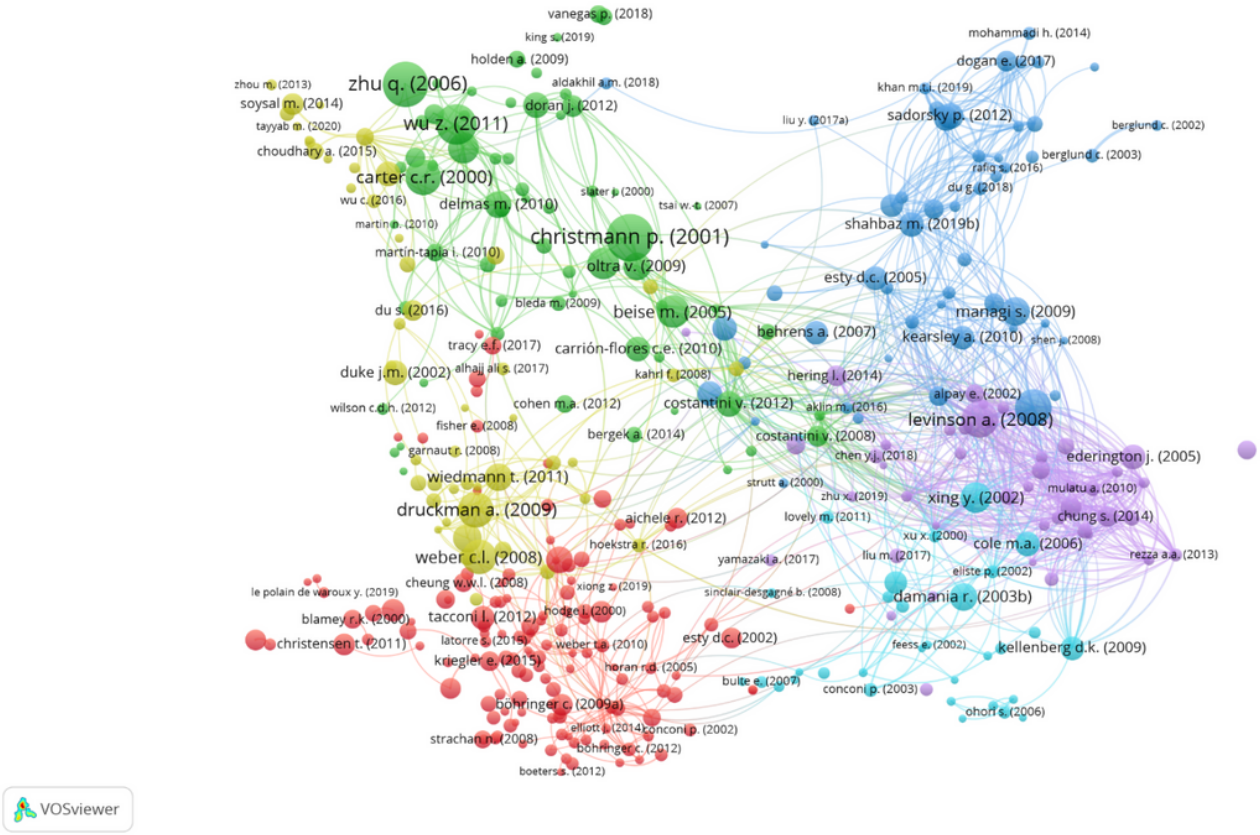

Figure 9

Bibliographic Coupling (Source: VOSViewer, based on the Scopus dataset)