A visualization review analysis of the last two decades for Environmental Kuznets Curve "EKC" based on co-citation analysis theory and pathfinder network scaling algorithms

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Abstract: Environmental Kuznets curve (EKC) is a statistical tool to examine the cointegration and causality nexus between economic growth and carbon emissions. The EKC is widely used in energy and environmental economics studies. Although, a large number of researchers have analyzed the EKC by applying different statistical models, and some review work has been summarized to draw a pictorial view of extending studies in this research field. However, still, the macroscopic overview needs to be considered. Therefore, this study aims to contribute to the literature for finding a new pathway for further research employing, and to facilitate this research Scientometric analysis is carried out by feature in CiteSpace. The dataset of screened 2384 records out of a total of 59225 Web of Science (WoS) references for the timespan 1999-2019 was used to visualize the knowledge map and outcome of the scientific enterprise. The visualization results reveal the most influencing studies, institutions, authors, countries, keywords, and category cloud, in the research field of EKC. This paper reveals that the research on EKC in alignment with green and sustainable technology science requires more attention. Further, this paper would help authors and publishers make their decisions for the research of EKC and planning for future perspectives to contribute to academic development and applied methodology.

Keywords: Environmental Kuznets Curve (EKC), Bibliometric, Scientometric Analysis Algorithm, Co-citation, Visualization, CiteSpace

1. Introduction

Environmental Kuznets Curve (EKC) so-called hypothesis is running from economic development to environmental degradation. In other words, EKC is a commonly used tool to identify the nexus between economic growth and the environment. First time in (1991) Grossman and Krueger used this tool to identify the environmental influence on free trade agreements for North America. Their results revealed that sulfur dioxide and smoke gradually rise in parallel with economic growth but at the low level of the national economy. These results were confirmed by World Bank in 1992 and published in a report in 1997 (Programme 1997). The dominant environmental degradations increase in parallel with income until the turning point hitting becomes steady and moves downward. In 1955, inverted-U shaped relationship was found by Simon Kuznets who presented a comparable nexus between income disparity and growth in economics (Kuznets 1955). Once an economy starts running towards development, it heavily puts footprints on the environment at the first step of economic growth. This can be observed in the form of air population, decreased soil fertility and increase in water contamination, etc. Previously, economic growth decreases and pollution increases, but beyond per capita income that rises and falls due to some factors and time trends. Therefore, it was a concept that high income ultimately leads to growth in pollution (Stern 2004). Possibly inexorably, the increasing strand of this literature review has been critical, claiming that the hypothesis of the Environmental Kuznets curve is brittle. Therefore, it needs a very cautious concentration for clear understanding (Fang, Huang et al. 2020) The hypothesis of EKC suggests that the early leg of economic growth is considered due to the overuse of natural resources which ultimately reduce the availability of natural resources and causes to increase pollutant in an ecological environment (Balsalobre-Lorente, Shahbaz et al. 2018; Sarkodie and Strezov 2019).

In earlier research, many research papers were formulated based on the EKC hypothesis in order to find the relationship between environmental quality and economic growth (Panayotou 2016; Tiba and Omri 2017). The hypothesis of EKC reveals that there is indeed a unidirectional causality extending from economic growth to deterioration of the environment or declares inverted-U shaped nexus among income and environmental quality (Orubu and Omotor 2011; Ahmed and Zeshan 2014; Conrad and Cassar 2014; Shahbaz, Nasreen et al. 2015). Thus, it can be said that economic development will finally untie environmental influence at the initial stage of economic development (Blind 2012). From the dearth of literature, many researchers use the EKC hypothesis for investigating the nexus between CO_2 emissions, energy consumption, and economic growth (Ozturk and Acaravci 2010; Al-Mulali 2011; Xue, Geng et al. 2014; Haseeb and Azam 2015; Ozturk, Al-Mulali et al. 2016). Early research confirms the EKC for Algeria by Bouznit and Pablo-Romero (2016) and for Eastern and North African countries Arouri, Youssef et al., (2012), for subsehrah Africa Ozturk and Bilgili., (2015), EKC confirmed by Demissew Beyene and Kotosz (2020). For India EKC confirmed by Sinha and Shahbaz (2018), Sinha and bhattacharya (2017), for Qatar by Mrabet and Alsamara (2017), for BRI countries by Rauf et al. (2018), for south Asian countries Nasreen et al., (2017), and Ahmed et al., (2017), for Nigeria by Nnaji et al. (2013), Joo et al. (2015), Mesagan (2015), for Portugal Shahbaz et al (2015), for Pakistan by Haseeb and Azam (2015)Mirza and Kanwal(2017), Sharif et al. (2017), Aziz et al. (2020), for China by Solarin et al. (2017), Yuan et al. (2015), Riti et al. (2017), Koondhar et al. (Koondhar, Qiu et al. 2018), (2020).

The EKC is the statistical concept, however, most of the studies based on the EKC analyzed, are not statistically reliable (Akbostancı, Türüt-Aşık et al. 2009). From the literature, it is clear that especially in developed countries concentration of pollution contribution in the environment decreases, but still, there is a relatively lower clearance of pollutant emissions (Smith 2013; Stern 2014). Apart from national economic growth conducted studies on running nexus from per capita income to the pollution that effort evades too many statistical drawbacks in order to investigate per capita pollution increase in parallel with per capita income. The developed countries' economic growth is relatively lower, and pollution decreases with parallel in the speed of growth effect. It seems, there is a significant and positive sign of existence of EKC effect. These results reveal that, although pollution problems are highlighted in developing countries, still there is no evidence to vicissitudes in pollutions.

Nowadays, Bibliometrics is the widely used statistical method to analyze scientific publications and understand the past, present, and future trends in certain fields of research. Bibliometrics uses citation analysis technique as opposed to the existing review/survey papers and constructs the citation graph, a network or graph representation of the citations between documents to measure the impact of their field, the influence of a group of researchers/countries/institutes, and the intensity of specific research, journal or author. The furthermost usual research was done on co-citation nexus, keywords linkages, and an association between co-authors. Considering the association of co-citation, if there are two studied and the third paper published and cited earlier published both papers so-called co-citation (Saini, Dutta et al. 2020; Sheikhnejad and Yigitcanlar 2020). This technique is more reliable and easy for aspirant researchers to understand a certain research field with heavy literature data. Bibliometric mapping technique not only provides a pictorial description of the state of the sculpture in the world of research but also deliver direction for scientists in emerging their area of research interest on a specific topic, hypothetically signifying stimulus for future theoretical and practical approaches to enlarge a specific field of existing literature.

Bibliometrics analysis previously has been used in several studies for different research directions. A recent study published by Sun et al. (2020) used a bibliometric approach in the research field of air pollution and child health. For a sustainable landscape in an urban and rural area, Sheikhnejad and Yigitcanlar (2020) used the same technique. The energy consumption paradigm in the agricultural industry for China is analyzed by Wei et al. (2020). Li et al. (2019) used visualization analysis for the impact of nanomaterials in the environment. Research on the resource recycling industry is done by Wang et al. (2019). Knowledge mapping for the research area of business and management is investigated by Jia et al. (Jia, Wei et al. 2019). In previous research, different researchers used different econometric models to identify the correlation between solitary variables. However, we use bibliometric analysis to find the research gap from the previous literature. Although numerous authors have already used bibliometric analysis in different research areas, no one scholar has visualized EKC using bibliometrics. In this study, we use the retrieved data from the web of science (WoS) on the research field of EKC for the last two decades and analyze the network mapping visualization, with objectives to find the pathway of research gaps in the research field of EKC. This research will contribute to literature for the future trend of research. I will also help researchers to do the research which is not previously done. In addition, this research will also help the young scholar to find potential institutes, professors, and countries for further studies or collaboration. May this study will also be valuable

for the journals to bring their pathway and authors to choose the journal for their research. Bibliometric is not only focusing on specific methods and research area, researchers can use this study as model to visualize another research field in order to efficiently find missing research links, journals, institutions, active researchers, and future trend of the research.

2. Methodology

2.1. Data Collection

In order to have relevant research papers in the dataset, the selection of literature was done carefully and only papers from trusted core collections of WoS were selected. Science Citation Index Expanded (*SCIE*), Social Sciences Citation Index (*SSCI*), Conference Proceeding Citation Index Science (*CPCI-S*) and Conference Proceedings Citation Index-Social Science and Humanities (*CPCI-SSH*) indexes and time period of last two decades "1999-2019" were set for the data set retrieval. In this time period of two decades, climate changes and CO_2 emissions have signified footprints, population and urbanization are increasing with timespan owing to reducing limited available resources. The topic selection word was the Environmental Kuznets Curve "EKC". The total 2360 articles direct and indirectly linked with EKC were retrieved and then imported into the Bibliometric tool CiteSpace for the visualization analysis of different categories supported by the tool. This study didn't collect the papers by traditional searching survey on google scholar. Firstly, the main reason was traditional survey is the time consuming method. Secondly it can't gives accurate information may we also miss some important literature. Third, the selected paper from WoS present a broader view of the EKC research field, and give a pictorial picture of both relevant and irrelevant articles. Fourth, available review and survey papers in the field are not based on the citations. The number of times a paper is cited reflects its research worth, and papers with similarities are commonly cited together. Thus, co-citation based analysis of research articles, authors, journals, countries, and institutions is more intuitive in revealing research structure, analyzing the developments and predicting the future directions in specific research area {Memon, 2020 #1001}. The detail of data collection is summarized in Table 1.

Table 1: Data Set

Indicators	Description
Acquired Data from Database	WoS
Data indices	SCIE, SSCI, CPCI-S, CPCI-SSH
Language and Document type	English, all documents or articles only
Topic selection words	Environmental Kuznets Curve EKC
Timespan	1999- 2019
Records for EKC	2384

Note: The data retrieved from WoS accessed from NWAFU library

2.2. Visualization Tool

The standard Citespace tools analyze the theoretical and pathway network map of co-citation references with scaling algorithms. Intellectual turning points play a key role in the development and construction of scientific fields. Through classifying these turning points, Citespace helps the author to find a missing research link in a certain research field and grasp a clear understanding of the field. Chaomei Chen in 2004 developed Citespace software, which is updated in time to time by Chen's research team of Chen (2004),(2006). The latest updated version is available at

https://sourceforge.net/projects/citespace/files/latest/download. Author co-citation analysis "ACA", one of the key features of CiteSpace, was introduced by White and Griffith (1981). ACA is used to classify and visualize the intellectual formation of a particular research area (Jeong, Song et al. 2014). Citation frequency is the foremost foundation of present ACA tool. Considering the co-citation analysis between related studies for a certain research field, the knowledgeable bases, research facades, and expansion trends in the field can be visualized. Therefore with the help of visualization analysis author efficiently can conduct in-depth research on a certain research area.

2.3. Visualization Results and Analysis

This paper presents 11 different visualization analyses related to the research field of EKC for the two decades using Citespace. These visualizations include co-citation visualization, cooperation visualization, and co-occurrence visualization by analyzing cited references, cited journal, country, institution, author, keyword, category, and overlay of visualization.

2.4. Visualization of Cited References

Cited reference visualization is a graphic reference map, which identifies the most significant studies in a particular research area. For the research area of EKC, time-slicing was selected from 1999-2019 with 1 slice per year, node type selected was set as "Cited reference" and strength of correlation was measured based on the Cosine metric (Equation-1):

$$Co\sin e(\mathrm{a},\mathrm{b}) = \frac{C_a C_b}{\|C_a\|\|C_b\|} \qquad (1)$$

where $C_a\, C_b$ denotes the co-citation reference of paper (a) and paper (b), while $\|C_a\|$, $\|C_b\|$ sign for citation time of paper a and b respectively. The filtering strategy of Top N (N = 100) strategy was used which implies that only Top number of records in terms of citation frequency during the year/slice would be selected for the visualization of 2384 references as shown in Figure 1. Based on the ACA, among the top 10 authors in citation count by Stern (2004) ranks the first. He argued that the EKC causes to increase in the environmental degradation curve and fallen by the increase in per capita income. Halicioglu (2009) ranked second with a citation count of 1268. His studies present the conclusion in two forms, considering the long-run nexus of first form carbon emissions resolute by consumption of energy, foreign trade, and income as well. While in the long-run association of 2nd form income determining causes to foreign trade, carbon emissions, and energy consumption (Halicioglu 2009). The third top-ranked work with a citation count of 892 is published by Jalil and Mahmud (2009). The results conclude that the quadratic association varies from income to carbon emissions, and the long-run and short-run nexus was confirmed by the test of the stability of the model. Another cited author analyzed the nexus between energy consumption, economic growth, and CO_2 emissions for countries in the middle east and North Africa countries, using panel data from 1981-2005. Authors concluded that long-run energy consumption significantly causes carbon emissions, and may in future carbon emissions reductions by reducing per capita income (Arouri, Youssef et al. 2012). In previous literature, the study concluded that carbon emission tends to increase by per capita income (Cederborg and Snöbohm 2016; Yeh and Liao 2017). Kasman and Duman (2015) also used panel data for EU member and candidate countries in order to find causality carbon emissions, energy use, trade, growth in economics, and urbanization. The results found that short-run unidirectional

cointegration is varying from the use of energy towards the international exchange and carbon emissions to urbanization (Table 2).

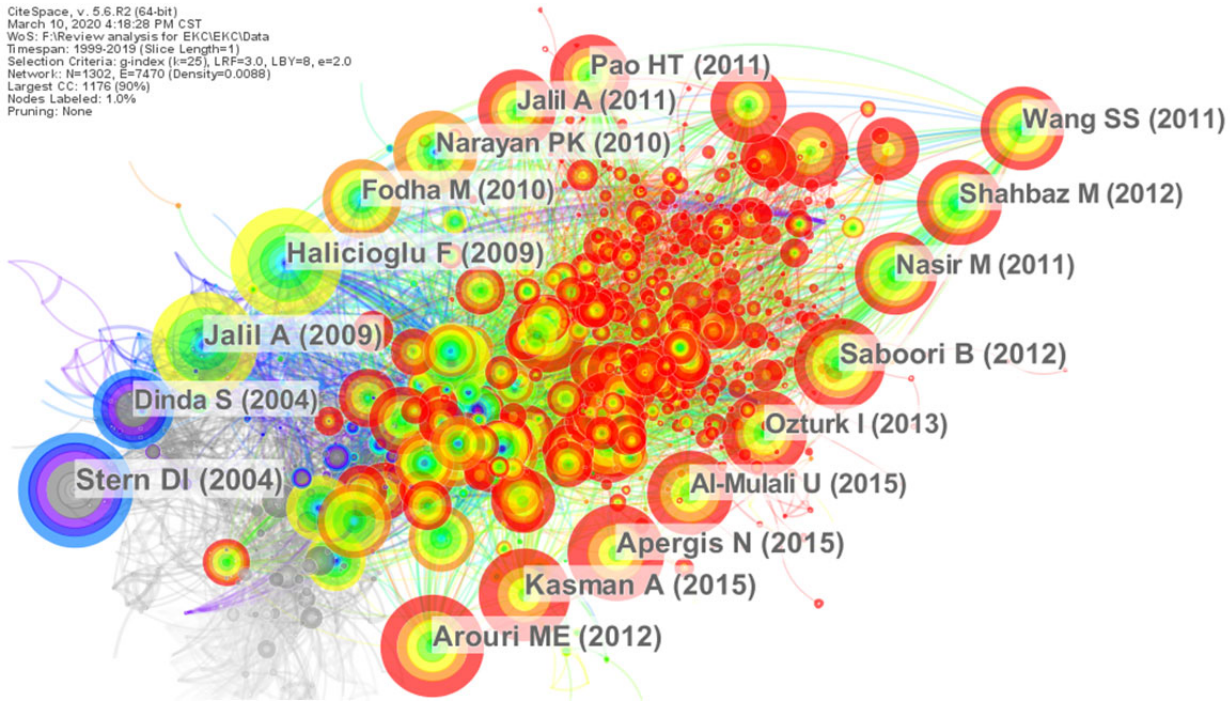

Figure 1: Reference Co-citation Map Visualization

An earlier study conducted by one of the most cited reference author, this study attempt to analyze the correlation between economic growth and CO_2 emissions for Malaysia (Saboori, Sulaiman et al. 2012). The results of this study reveal that long-run association from carbon emissions towards per capita GDP also confirms the inverted-U shaped curve running from CO_2 emissions to GDP both in the long-run and short-run axis. The results of this study are contrary to previous research (To, Ha et al. 2019). Another study also found an inverted-U shaped curve between carbon emissions and per capita income (Apergis and Ozturk 2015). Nasir and Rehmand (2011) estimated the environmental Kuznets curve for carbon emissions in Pakistan. However, the results of their short-run association denied having EKC between selected variables. Furthermore, one of the studies was estimated EKC for Vietnam results reveals that EKC does not exist due to both long-run and short-run nexus GDP and pollution declares positive and significant relationship (Al-Mulali, Saboori et al. 2015). Moreover, the existence of EKC was confirmed by VECM and IAA technique for Tunisia (Shahbaz, Khraief et al. 2014). Among the top 10 most cited authors, most of the papers were published in energy policy.

Table-2: Top 10 Co-cited Authors based on Citation Counts

Citation Counts	Authors	Journal Name	DOI
2947	Stern (2004)	World Development	https://doi.org/10.1016/j.worlddev.2004.03.004
1268	Halicioglu (2009)	Energy Policy	https://doi.org/10.1016/j.enpol.2008.11.012
892	Jalil and	Energy Policy	https://doi.org/10.1016/j.enpol.2009.07.044

	Mahmud (2009)		
593	Arouri et al. (2012)	Energy Policy	https://doi.org/10.1016/j.enpol.2012.02.042
470	Kasman and Duman (2015)	Economic Model	https://doi.org/10.1016/j.econmod.2014.10.022
451	Saboori et al. (2012)	Energy Policy	https://doi.org/10.1016/j.enpol.2012.08.065
350	Apergis and Ozturk (2015)	Ecological Indicators	https://doi.org/10.1016/j.ecolind.2014.11.026
334	Nasir and Rehman (2011)	Energy Policy	https://doi.org/10.1016/j.enpol.2011.01.025
202	Al-Mulali et al. (2015)	Energy Policy	https://doi.org/10.1016/j.enpol.2014.11.019
186	Shahbaz and Lean, (2012)	Renewable and Sustainable Energy	https://doi.org/10.1016/j.rser.2012.02.015

Note: Author visualized this in Citespace v.5.6.R2

Citespace also presents the clustering visualization of all the papers in the dataset. Clustering visualization uses a log-likelihood ratio (LLR) algorithm to combine the papers with a common theme/area/problem addressed in one cluster/group. The LLR is a statistical test used for comparing the goodness of fit of two statistical models, and also shows the trends of a null model against an alternative model. The test is based on the likelihood ratio, which expresses how many times more likely the data are under one model than the other. This likelihood ratio, or equivalently its logarithm, can then be used to compute a p-value, or compared to a critical value to decide whether or not to reject the null model As a result, papers in one cluster present the same research domain and different clusters present the overall research domains of the field. These clusters are characterized by silhouette values, which indicate the relativeness of the papers in the same cluster. The first largest cluster in our analysis has 217 members and a silhouette value of 0.809. It is labeled as an Environmental Kuznets Curve by both the LLR algorithm. The most active citer to the cluster is Dinda, (2004), Environmental Kuznets Curve hypothesis, and this paper was published in the Ecological Economics journal. In this paper, the author argued that EKC has an inverted-U shaped curve along with non-identical emissions and income per capita. He acquires that environmental coercion of specific reasons leads to an increase in income. Considering the 2nd largest cluster has 199 members and a silhouette value of 0.688, and labeled with energy consumption reading ability by LLR algorithm.

Considering energy consumption paper was published in Natural Hazards, published by Al-Mulali et al. (2015) entitled the impact of emissions in Europe by growth in economics, international trade, urbanization, financial development, and renewable energy, and argued that carbon emissions, economic growth, increasing urbanization pressure, and production of renewable energy has cointegration at the level. Furthermore, they concluded that generating renewable energy shows a negative long-run association with carbon emissions. The third-largest

cluster with 152 members and a silhouette value of 0.759 is labeled as developing countries. In this era, the most active cited paper discussed developing countries with health security, infrastructure, and livelihood. In the 1st part of the results the author discussed the health correlation with a pathway of production and utility and in 2nd part he mentioned the stock approach, increasing income, and welfare change the policies for taxation in income along with public consumption (Agénor 2008). Also, the 4th largest cluster is labeled as a cross-national study with 134 members and a silhouette value of 0.895. Considering the most active citation paper with the clustering of 13671, we discussed the human dimension of greenhouse gas and global warming due to deforestation in many developing countries, the leading causes of deforestation considering the increasing rate of urbanization. The 5th largest cluster has 133 members and a silhouette value of 0.812, and LLR is labeled as an ecology footprint. This is a recently published study, this study was investigated for Malaysia in 2019 using time series data for 1971-2014. The major findings of this study reveal that globalization does not confirm the positive association with an ecological footprint, increasing population causes to reduce ecological and carbon footprint (Ahmed, Wang et al. 2019). Cao, Chai et al (2020) concluded that the increase in population significantly reduces the biodiversity and ecosystem. Further see Figure 2 in order to understand the time trend of reference citations.

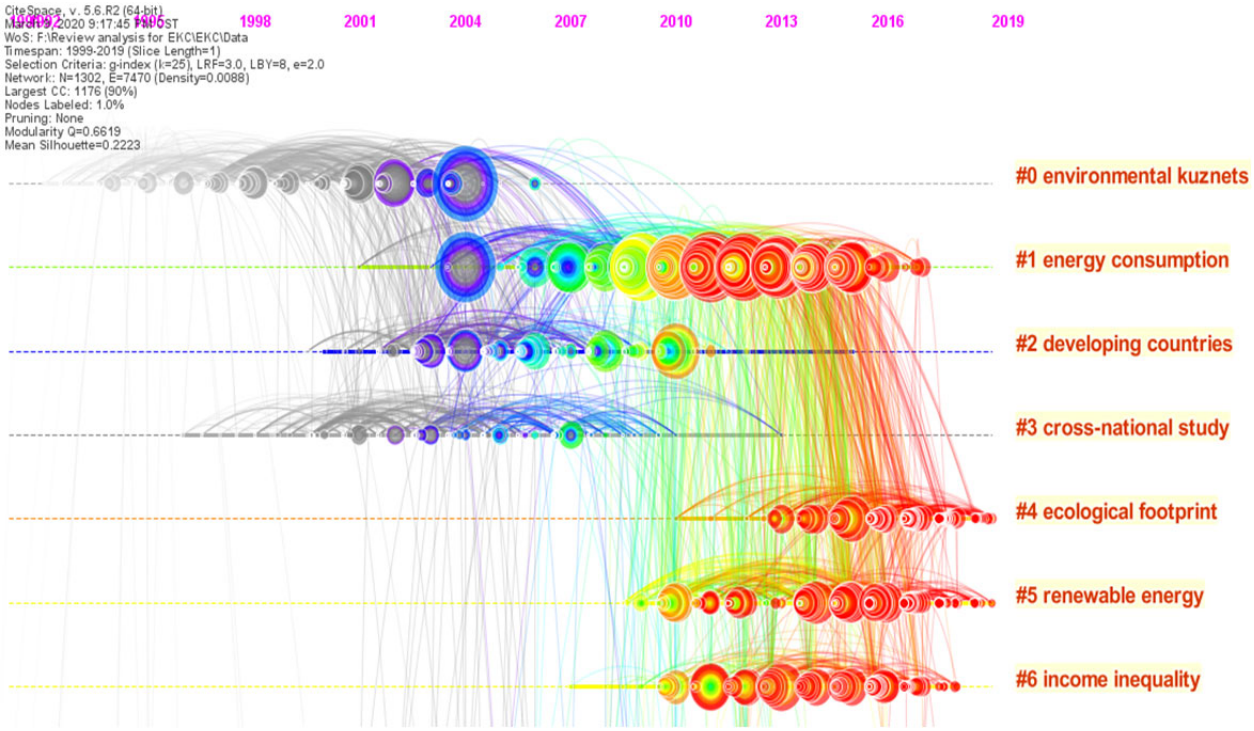

Figure-2: Reference Cluster Co-citation Visualization Map

2.5. Visualization Map of Research Journals

Journal citation is another feature of the citespace to analyze the visualization of research journals based on the co-citation by setting node type: cited Journal. For the journal map Visualization for 2384 records was performed and the top 10 most cited journals were selected for easy understanding, shown in Table-3 and Figure-3.

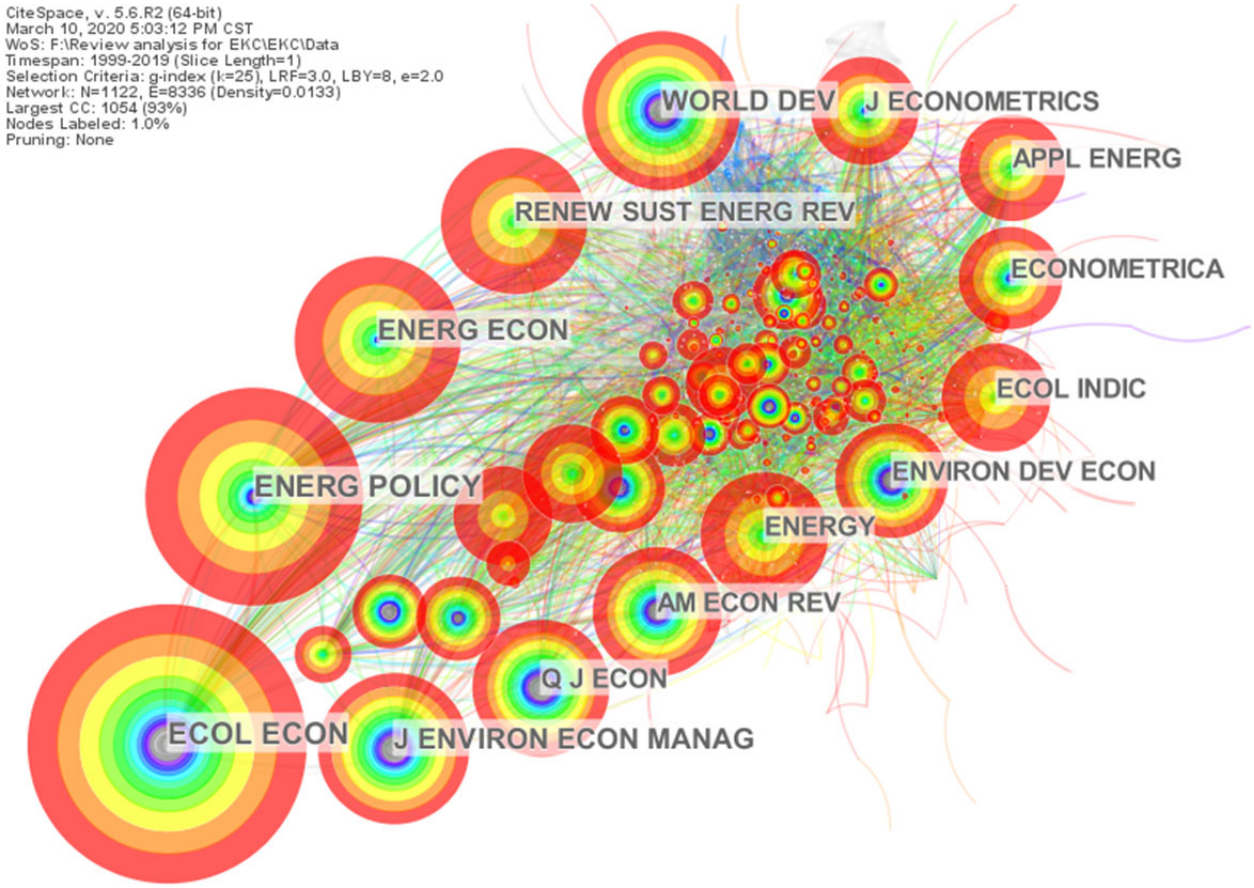

Figure 3: Journal's Visualization Map

Table 3: Selected the Top-10 Journals by Citation and Cluster Frequency

Frequency	Full journal name	Abbreviation	Publisher	I.F 2018-19
1973	Ecological Economics	Ecol Econ	Elsevier	4.281
1517	Energy Policy	Energy Policy	Elsevier	4.880
1177	Energy Economics	Energy Econ	Elsevier	4.151
1174	World Development	World Dev	Elsevier	3.905
1107	Journal of Economics environmental management	J Environ Econ Manag	Elsevier	4.175
1019	Renewable, sustainable energy review	Renew Sust Energ Rev	Elsevier	10.556
1015	The Quarterly Journal of Economics	Q J Econ	Oxford Academic	11.77
984	The American Economic Review	Am Econ Rev	American Economic Association	11.889
923	Energy	Energy	Elsevier	5.537
861	Environment and Development Economics	Environ Dev Econ	Cambridge Core	1.217

Note: Author visualized this in Citespace v.5.6.R2

Considering the journals' visualization network from which publishers may identify the contribution of the journal in the research field of the environmental Kuznets Curve. Table-3 declares the most-cited journal in the scientific research of EKC are Ecological Economics, Energy Policy, Energy Economics, World Development, Journal of Economics Environmental and Management, Renewable and Sustainable Energy Review, Quarterly Journal of Economics, American Economic Review, Energy, and Environmental & Development Economics. Among the top 10 journals, 7 journals are published by Elsevier. Ecological Economics has top ranking by citation counts 1973, this journal concerned with increasing and assimilating the acknowledge of the lines and interplay between ecosystem and economy. Ecological Economics is an interdisciplinary discipline defined by a series of specific issues or difficulties associated with regulating economic operations in a manner that facilitates human excellently-being, prosperity, and equality. The 2nd one journal ranked in the top 10 listed journals is Energy Policy with a citation counts of 1517. Energy Policy is a peer review international journal, who covers the paper related to addressing policy implications use in energy consumption, economics, social and environmental aspects. Energy Economics journal is known as the third-ranked journal with the citation counts 1177. This journal is the best journal for energy economics and energy finance related papers. But it also accepts the papers related to environment and climate, energy consumption, energy commodities etc. The 4th is a world development journal in cluster 16, with citation counts of 1174. This journal aims to discover a pathway of improving standards of living and the human by investigating the problem such as poverty alleviation, finance, and environment influence so on. Considering the top 5th and 6th Journal of Environmental Economics and Management, and Renewable and Sustainable Energy Review, generally in light view both journal aim is the same to improve economics with a healthy environment. The Journal of Environmental Economics and Management focuses on natural resources and the environment, and, Renewable Sustainable and Energy Review-journal tied together and bring together the consumption of energy and the environment. The conclusion results in Figure-3 and Table-3 based on visualization analysis of the last two decades would support both researchers and publishers to make their decisions for the research of EKC and contribute to academic development and applied methodology in their future perspectives. It is most important to provide your research best home, therefore it is essential to select the journal very carefully, first of all, check the journal's impact factor and citations score, 2nd check the journals abstracting and indexing services, 3rd publisher's prestige is also important to be considered while selecting the journal, and online submission with tracking facility (Wijewickrema and Petras 2017; Suiter and Sarli 2019).

2.6. Country and Institutional Map of Visualization

Country Visualization is one of the compulsory visualizations to know the most active research country focusing on environment. Selecting node type as a country with a citation threshold of 50, we retrieved the visualization for 2384 published studies on the EKC algorithm, shown in Figure-4.

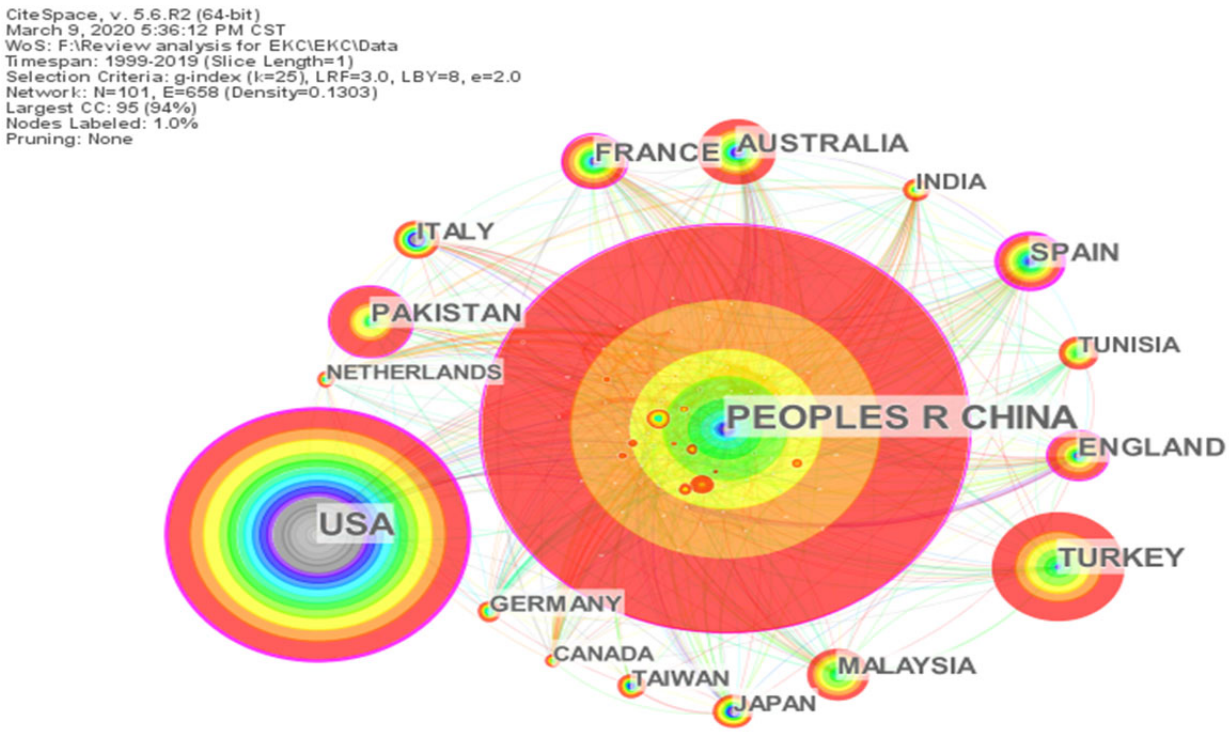

Figure 4: Countries' Visualization Map

Considering the citation map of countries, China, the USA, Turkey, Australia, Pakistan, Spain, France, England, Malaysia, and Italy are the most activated countries which are focusing on climate change research. As China is listed at the top of the country and 2nd listed as the USA. What are the different colors acquires for China and the USA that, China is one track towards the development, and leads to pollution at the same speed of development. Therefore, China is doing much research related to climate change. The USA is an already developed country, seems the USA has already adopted green technology with economic growth. Considering the research output China is closing the gap with the united states on research spending (Viglione 2020). Australia, Italy, Germany, France, Spain, Japan, Canada, and England focus on the algorithm of EKC in the earlier stage. Therefore the hot period of each country seems to have different. Furthermore, the research interest related to climate change extended to more countries i.e. Greece, India, Pakistan, and Malaysia. Apart from county visualization, it is also important to discover which institutes research and publication had the most effect on the Environmental Kuznets Curve. We also conducted institution visualization by choosing an institute note type, we got the institutional visualization 2384 reference after 1408 iterations.

Table 4: Selected Top 10 Institutions Focusing on EKC by Cluster Frequency

Frequency	Institution Name	Location Country
85	*Beijing Institute of Technology*	Beijing, China
70	*Chinese Academy of Sciences*	Beijing, China
44	*Cag University*	Mersin Turkey
37	*collaboration innovation center of electric vehicles in Beijing*	Beijing China
34	*Sustainable development research*	Beijing China

	Institute for *economy* and *society* of *Beijing*	
33	*Beijing key lab of energy economics & environment management*	Beijing China
33	*Eastern Mediterranean University*	North Cyprus
32	*Xiamen University*	Fujian China
31	*COMSATS Institute* of *Information Technology*	Islamabad Pakistan
30	*North electric and Power University from China*	Beijing China

Note: Author visualized by Citespace v.5.6.R2

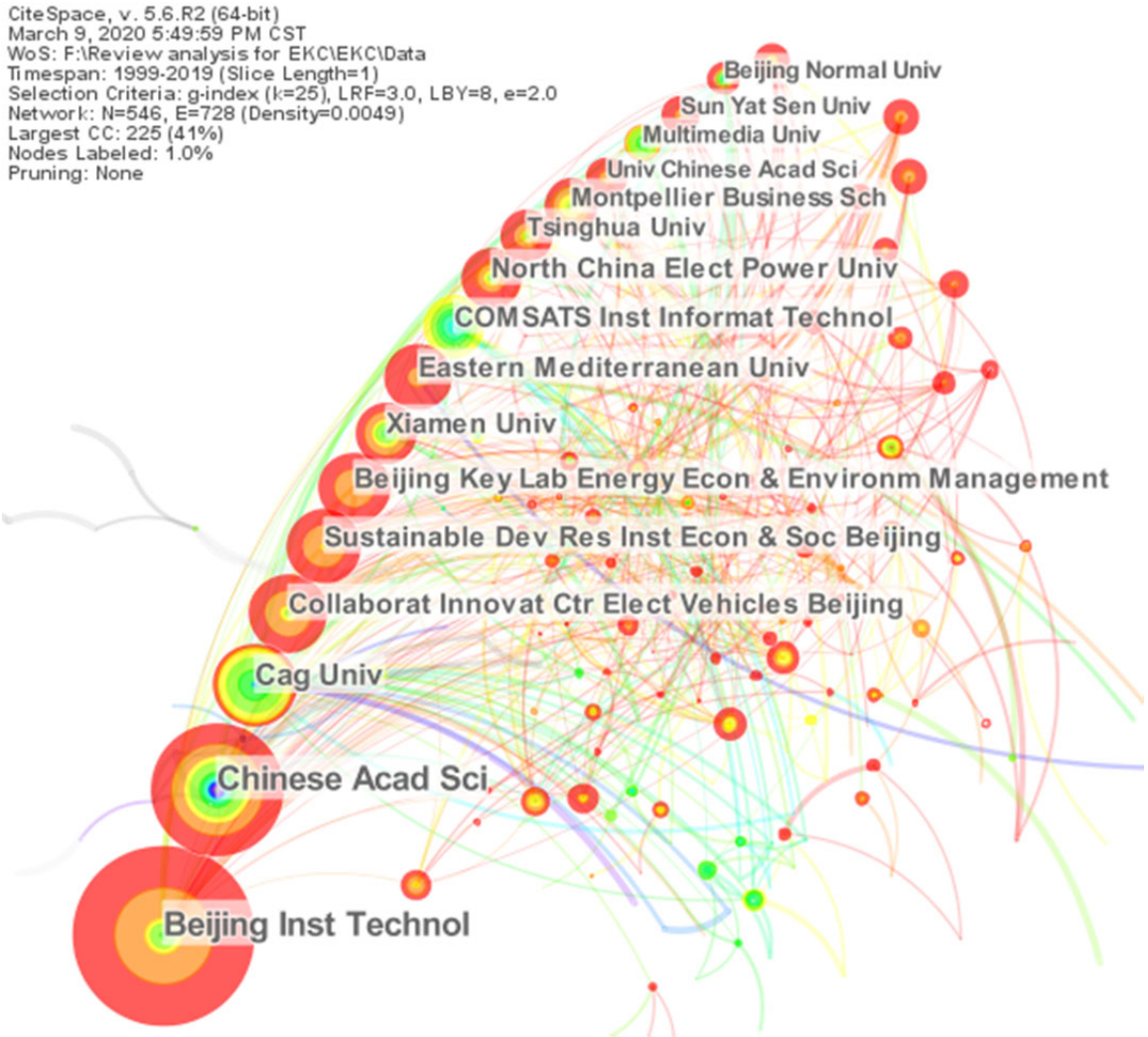

Figure 5: Institutions Visualization Map

Given Figure 5 and Table 4 are the institutes that are most active and influential doing research on the EKC algorithm are mainly from China, Turkey, and Pakistan. The top one institute of China is the Beijing Institute of Technology (BIT) established in 1940 in Yan'an, Shaanxi Province, and was relocated to Beijing in 1949. In 1952, the school was renamed Beijing Engineering College, the first Defense Industry University in the PRC. In 1988, the school was renamed the Beijing Institute of Technology. Beijing key lab of energy economics & environment management, sustainable development research institute for economy and

society of Beijing, and collaboration innovation center of electric vehicles in Beijing these are the research labs of BIT. Chinese Academy of Sciences, Xiamen University, North Electric, and Power University from China, which are also actively doing research related to climate change and EKC. From Turkey participating in research in the same pathway are Eastern Mediterranean University and Cag University. COMSATS University is located in Islamabad Pakistan.

2.7. Authors Map of Visualization

Author visualization can help the researcher to find the most influential researcher in the EKC research area. Node selection = Author with the threshold of 50 was fixed to obtain author visualization for all the 2384 records, shown in Figure 6.

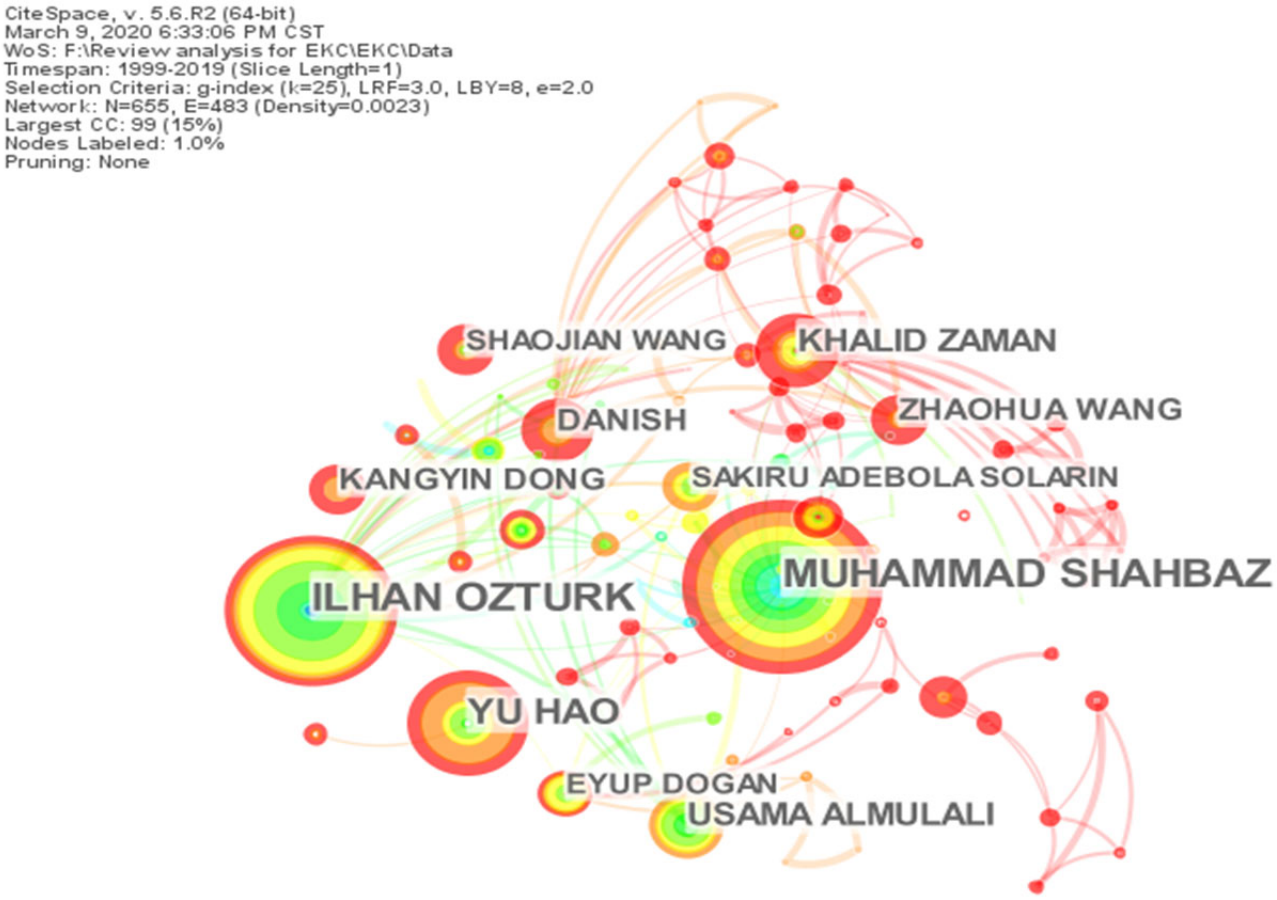

Figure 6: Authors Visualization Map

Among the most influential researchers, Muhammad Shahbaz ranked as the top one. Dr. Muhammad Shahbaz is a full professor at the School of Management and Economics, Beijing Institute of Technology, China. He primarily carries out research interests in economic growth, the economics of energy, ecology, and tourist etc. He has published widely in highly reputable peer-reviewed highly reputable journals. He is among the top 10 authors, who has summarized the IDEAS in the research field of economics categories. Most of the papers of Dr' Shahbaz published on carbon emissions with economic growth, for constructing the EKC (Shahbaz, Hye et al. 2013; Shahbaz and Sinha 2019). 2nd one is Ilhan Ozturk. He is also a full professor at the Faculty of Economics Administrative Sciences, Cag University Turkey. His research interest is

Energy Economics, Environmental Economics, Foreign Trade, FDI, Economic Growth, and in his research expertise, as a 1st or co-author published more than 150 papers in peer-reviewed international journals (Ozturk 2010). Yu Hao is a faculty member of the School of Management and Economics, Beijing Institute of Technology. He focuses on Energy Economy, Environmental Policy, Macroeconomics, and Quantitative Economics. Khalid Zaman is an Assistant Professor at Preston University Kohat, Islamabad. Dr. Zaman is working on the development and environmental economics and his top paper published on the nexus between tourism development, energy consumption, and EKC. Al-Mulali is a Malaysian scientist, and working as a senior lecturer at the business school of Multimedia University, Malaysia. His research interest covers renewable energy, environmental resources, pollution. His earlier study investigated the EKC for Vietnam to have maximum citations and contributions to the research of the EKC algorithm. The results declare no existence of the ECK hypothesis because the nexus of GDP has a positive and significant correlation with pollution in the short-run as well as in the long-run (Al-Mulali et al. 2015). Among the top 10 scientists, there are three Chinese scholars who are contributing to Environmental Kuznets Curve algorithm: Zhaohua Wang, Kangyin Dong, and Shaojian Wang Who are working at Beijing Institute Technology, China, Rutgers University-New Jersey, Sun Yat-sen University China respectively.

2.8. Analysis of Research Emphasis

2.8.1. Network Map of Keywords Visualization

The research focus was investigated by examining the keywords to find the pathway of research in a certain period of time, which indicates the discipline of large scale publications, the attentiveness of research concepts, and the appearance of a great number of researchers who are doing research in parallel (Leung, Sun et al. 2017; Wang, Zhao et al. 2020). From previous literature, a scholar argues that scientific development is an alteration of traditional science and modern science (Kuhn 2012). Which acquires that scientific research is changing with the time and income insurability among old and contemporary approaches, because the vocabulary changes accordingly. Therefore, we can observe that the existence of a revolution occurred by the changes in vocabulary. The statistics of the figure of keywords that occurred in the previous literature canister imitate the significance of keywords in this period to a specific research area (Wang, Guo et al. 2019). Thus, keyword co-citation can show a missing link of research in a certain specific research area. The co-word approach was first proposed by Callon et al. (1983), and wildly used in the research field of information science. The co-citation maybe useful for strategically selecting information that can build consilience about ideas and constructs that are relevant across a range of disciplines (Trujillo and Long 2018). The researchers served by co-citation are a member of what has been called invisible colleagues, bunch of researchers in often communicate with one another and involved with highly specialized subject matters (Small 1980). The concept of co-citation ideas in bibliometrics is driven from the co-word examination. Therefore, it is scientifically proved that when two scientific terms “inscription of keywords” exist in a published research work in the same time, indicates that there is a significant nexus between those two papers who have similar keywords, if the words appear more times, each time to time brings together to them (Zhang and Xu 2008). The bibliometric analysis is the sum of all co-citations, co-words, and co-term analysis.

Based on the frequency co-occurrence words analysis for the retrieved dataset of 2360 on the EKC, we present a list of top 10 co-occurred keywords in Table 5, and we can see that there are

two groups of co-occurred words, group one includes, Environmental Kuznets Curve, carbon emissions, energy consumption and all kind of pollutions, another group covers economic growth, income, trade for the country development with sustainable manners. These results are contrasted with the exploration technique of this study. The mutual appeared keyword CO_2 emissions, and carbon dioxide emissions generally refer to one word, different authors used different terms because of the used different emissions for different studies, such as greenhouse gases, nitrogen oxide, and methane etc.

Table 5: Selected Top 10 Keywords Frequency

Keywords	Frequency	Centrality
Environmental Kuznets curve	1436	0.89
Economic Growth	1251	0.84
CO2 Emission	941	0.84
Energy Consumption	652	0.82
Kuznets Curve	479	0.81
Carbon Dioxide Emission	395	0.74
Pollution	347	0.74
Income	345	0.73
Carbon Emission	344	0.73
Trade	336	0.71

Note: Author visualized this by using Citespace v.5.6.R2

The network map shows an objective of the web of knowledge, which expressed the map of scientific knowledge in a particular research area with a specific time period (Leydesdorff 1997). For the keyword map networking for this study, data was imported into CiteSpace and analyzed map of keyword network. Present nodes in Figure 7 each node shows a different keyword, and the size of each node shows the frequency of the keyword. The total number of nodes presented in figure 7 has 852 nodes, 6716 connections running between nodes, and 0.018 shows the density of the network. The most influential nodes are represented with thickness, and different colors of nodes signify to years. From the colors, it is clear that the Environmental Kuznets curve and economic growth appear in earlier years. Generally, keywords appear with time zone; it acquires that the development of economic growth and EKC are developed gradually. We can see in the figure the thickest node is EKC and 2nd one economic growth as we identified in Table 5. Furthermore, the connection between nodes is thick, which means most of the papers published in the research area of EKC based on economic growth, carbon emissions, multiple research connections such as per capita income, FDI, international trade etc., for development in livelihood, economic development with a sustainable and friendly environment.

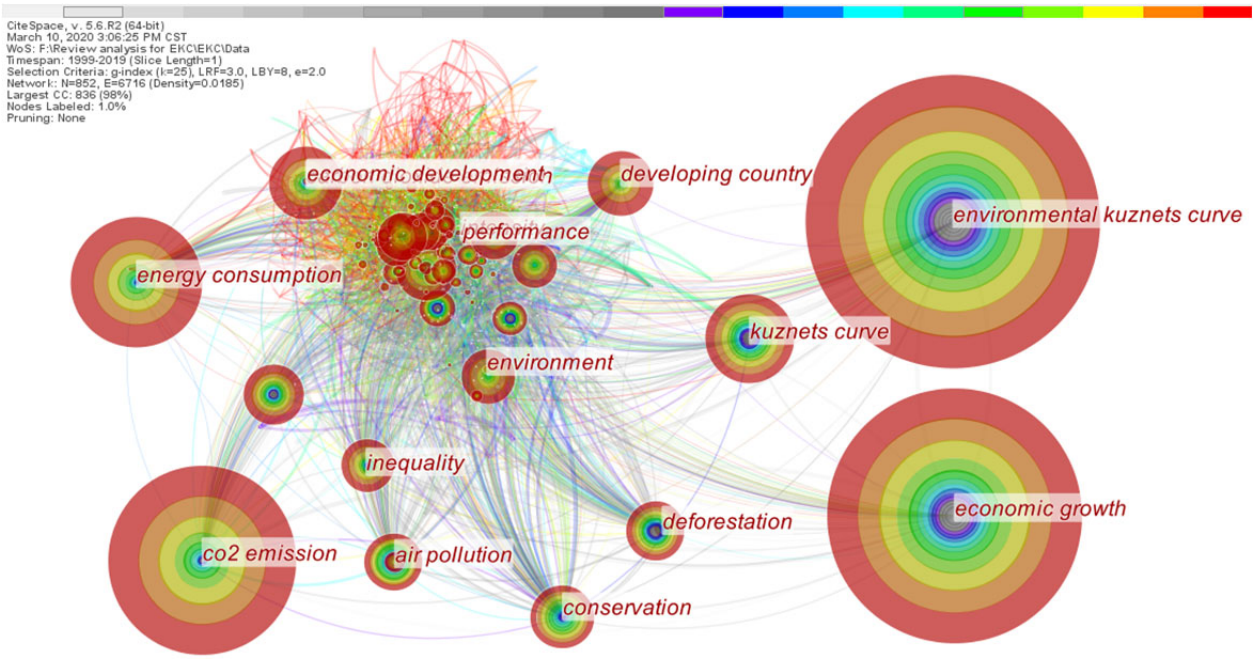

Figure 7: Keywords Visualization Map Network

Top 15 Keywords with the Strongest Citation Bursts

Keywords	Year	Strength	Begin	End	1999 - 2019
economic development	1999	6.4882	**1999**	2012	
developing country	1999	7.3958	**1999**	2010	
environment	1999	10.7756	**1999**	2012	
quality	1999	32.8432	**1999**	2013	
pollution	1999	38.5914	**1999**	2015	
emission	1999	25.3281	**1999**	2011	
intensity	1999	7.4135	**1999**	2010	
inequality	1999	16.6714	**2000**	2011	
biodiversity	1999	6.6429	**2001**	2011	
conservation	1999	6.2402	**2001**	2013	
economic growth	1999	5.4888	**2001**	2005	
kuznets curve	1999	15.7547	**2002**	2011	
deforestation	1999	18.2115	**2003**	2013	
policy	1999	10.4466	**2004**	2014	
trade	1999	5.5792	**2004**	2007	

Figure 8: Sorting out Emergence List of Keywords in Intensity of Burst

Furthermore, the pathfinder research analysis for the frequency of the keywords is more efficient to identify the emerging fields and improvement in the scientific literature of EKC. Therefore, in this research burst analysis is used following the theory of Kleinberg Algorithm (2002). Figure 8 shows economic development and pollution found to have high frequency with a certain time period. In addition, other efficiency keywords are also given a certain period of time.

3. Network Map of Category Visualization

Due respect to category visualization, we summarized into four cloud algorithms, environmental science, business & economics, energy & fuel, green & sustainable & technology science (Figure 9).

3.1. Cloud Environmental Science

Above recognized keyword, EKC is the proportion of environmental studies, includes ecology, and emissions. When global warming, air pollution become an issue and pollution runs in parallel with economic development, then environmental sciences play their role to manage the environment in sustainable manners (Pearce, Barbier et al. 2013). Environment science has documented and worrisome change system for climate change and biodiversity to change in hydrological and nutrients cycle and depletion of natural resources, which results to the loss in economic development (Polasky, Kling et al. 2019) therefore, it is necessary to consider the impact of the environment on economic growth, poverty and inflation are also causes of less development in economics (Organization 2018). Not only a significant proportion of clouds goes to EKC in keywords but also goes in category-wise visualization. It is worth noting that only big data and visualization analysis identified the EKC, and acquires the significant characteristics of the environmental Kuznets curve.

3.2. Cloud Business and Economics

As above in Figure 7 shows economic growth has a second significant proposition of cloud, similar here in category visualization analysis 2nd big proportion goes to business and economics includes international trade, economic growth, per capita income growth, and foreign direct investment (FDI). Economic development with a healthy environment is compulsory for humans and other living animals on this planet. Control of the environmental standard in the projects to improve environmental pollution and has attracted FDI of stability to achieve sustainable economic development (Nguyen 2018).

3.3. Cloud Green & Sustainable Science & Technology

As development for the country is necessary for increasing economic income as well as livelihood. We can see from the cloud visualization it is also necessary for development to have to use green and sustainable technology. Green and sustainable technology can output more with less carbon emissions. A mapping growth and trends in the category of green and sustainable science and technology study, and found the mainstreams determined on the grounds of co-word analysis (Pandiella-Dominique, Bautista-Puig et al. 2018). Therefore clouds give new research align to research green and sustainable technology science for sustainable development and green environment.

3.4. Cloud Energy and Fuel

Energy and fuel are one of the most useful sources of power in the world today; most of the fuel is naturally derived from the soil such as petrol and diesel. These energy sources not only provide power but play a key role in increasing carbon emissions. Fossil fuel per capita and energy consumption cause to increase in carbon emission (Huang, Krigsvoll et al. 2018; Ahmed and Shimada 2019; Liu, Lei et al. 2019). Therefore, due to the detection of energy and fuel as well as green and sustainable technology reveals that scholars need to pay attention more to research green and sustainable technology for a sustainable environment.

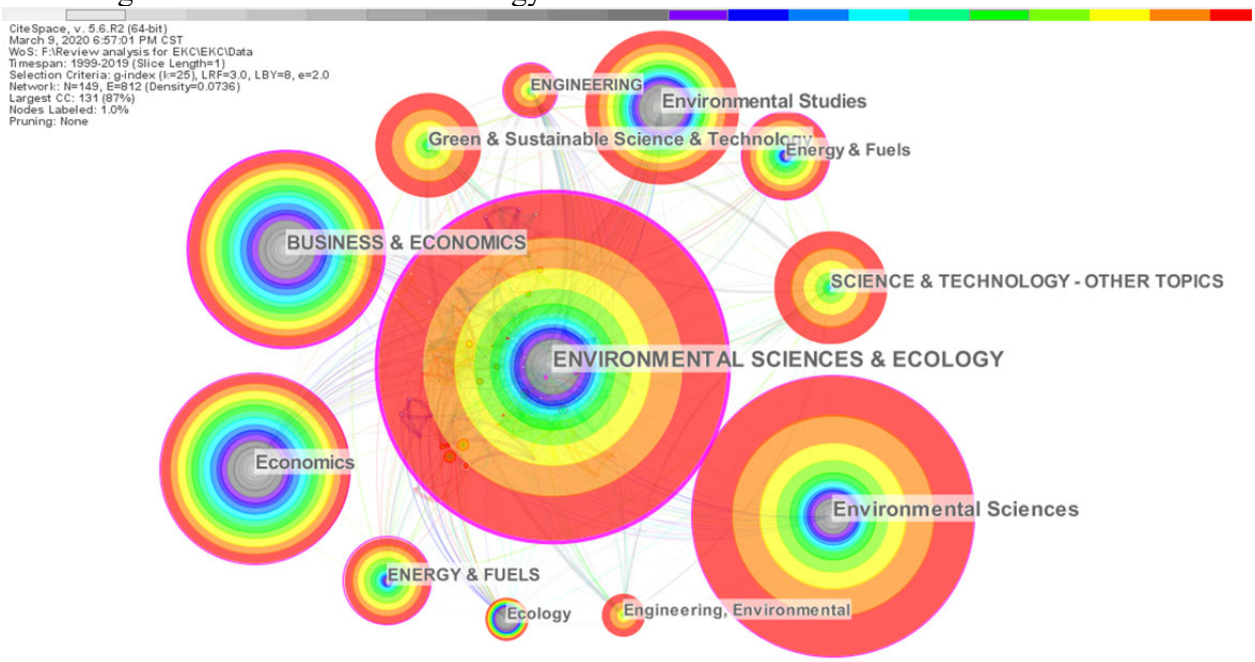

Figure 9: Category Visualization Map Network

4. Overview Network

Articles citing between earth, marine, veterinary science, environment, economics, and politics during 1999-2019 were identified by portfolio analysis given in Figure 10. The dual overlay overview generated for finding the efficiency and active journal citing and cited journals. Figure-10 was divided into 3 sections based on the simple overlay, adding overlay and applying trajectories by Z-Score. Given colors to section-1 and 2 are selected based on corresponding journal clusters.

Figure 10 shows the network of citing journals in the left side and the right side shows the cited journals map given in section one. Each map extracting journal titles reflects the discipline of the network. For the visualization information, we employed overlay to identify the overview of the literature for the research field of EKC. In section-2 of Figure-10 connote the linkages running from citing journals towards the cited journals, which implies how the publication of EKC is located on the left side and influences draw to journals outcome in the right side. Each circle identifies the number of authors are doing research on a certain research topic and how many articles are involved, cited journals are measured in the horizontal trend of the circle, and authors' involvement is measured vertical trend. Information visualization of yellow circle identifies the more than 200 papers published in Environmental Science and Pollution Research journal by the research connectivity of carbon emissions from livestock and economic growth.

While the blue circles are connoting mixed research trends of technology, economics, policies, development, and education. In the left side of section-2, cited journals declare trends running from the research of economics and politics towards ecology, earth geology, computing, biology, and forest. The increasing trend of energy consumption in every industry for development is resulting in carbon emissions. Therefore the journals and authors have a mixed trend with pure science and social science research (Wang, Ge et al. 2016).

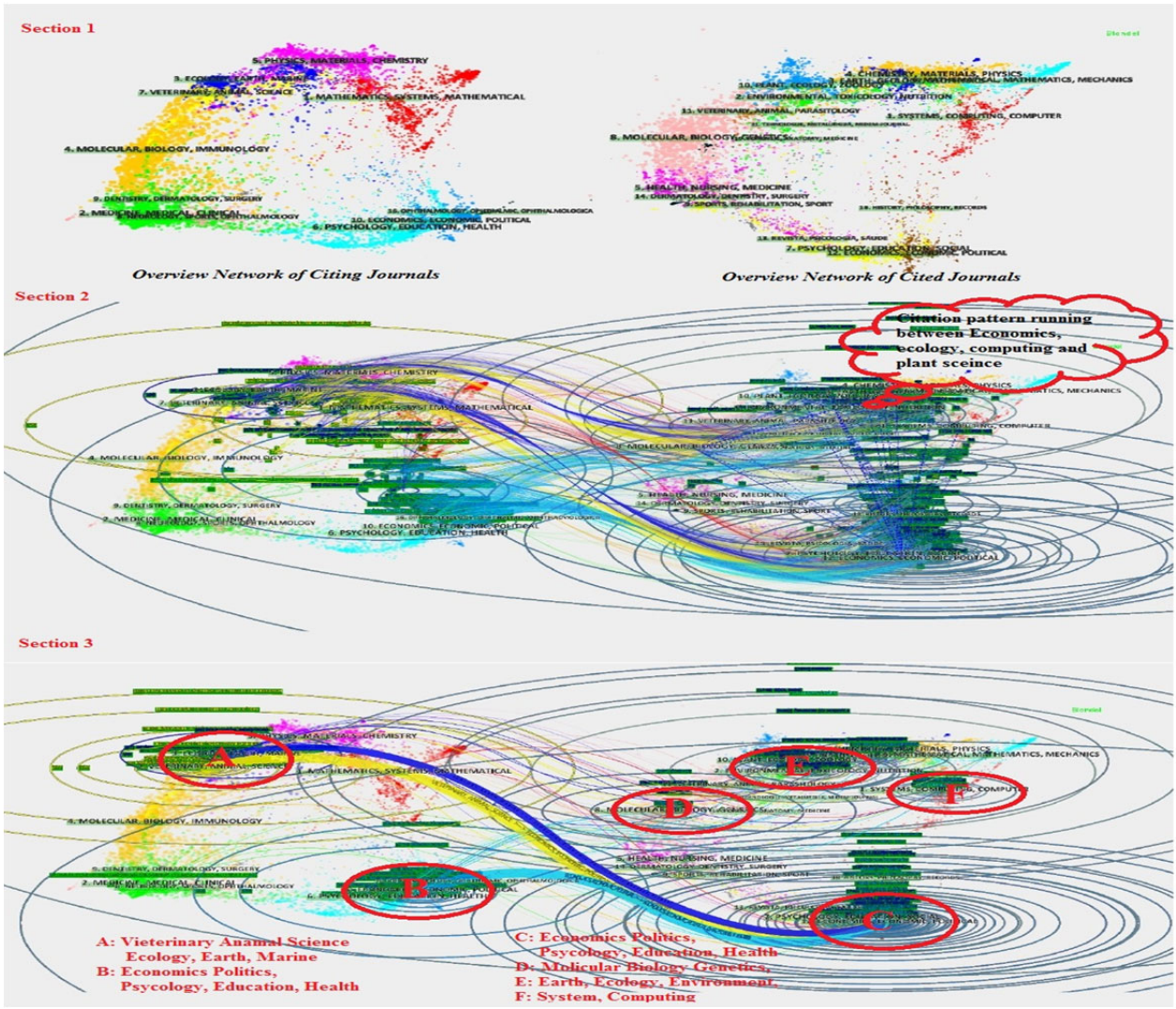

Figure 10: Dual-overlay Overview Network

Furthermore, in section-3 of Figure-10 results are summarized by applying a z-score for clear visualization information. Arcs mapping show section-A and B in citing journal areas are more active which are connecting to cited journals of the research field of economics, politics, education, and social. The most frequent journal yellow line shows the connection between veterinary animal science to economics, politics, education, and social. While the blue line declares a trend from ecology earth marine to psychology, education, economics, and politics. The mutual correlation between economics and politics is measured is given the sky blue line. The pattern of section-1, 2, and 3 reveals that citation arcs linkages between climate change

along with certain research fields, and these are straight forwards for authors to become familiar with the geography and connect the new alignment for future research.

5. Conclusion and Future Research

The Environmental Kuznets curve (EKC) is known as a hypothesis to identify the relationship between environmental degradation and economic growth. This research aimed to find the research gap in previous research and identify the linkages of authors, institutions, keywords in order to go through the new direction of research. From the dearth of literature, it is clear that enough work has been done for developed and developing countries regards climate degradation and economic growth. For this study literature data of 2384 records were collected from the Web of Science (Clarivate Analysis) for the last two decades (1999-2019). Visualization analysis was done by using CiteSpace 5.6.R2 software. The conclusion of this study summarized in 5 parts for easy understanding as follows:

(1) From the dearth of literature sorted the most active two published and cited papers in algorithms of EKC and economic growth, trade openness, and urbanization. In the literature, this paper contributed by Dinda's research team in 2004 at the economic research unit, India Statistical Institute, and Al-Mulali's research team contributed in 2015 from the College of Business, Multimedia University from Malaysia, and Cag University from Turkey. Besides these top two studies among the top 10 studies, other studies also have an underlay profound influence on the incentive and significance of the publications in the research area of EKC.
(2) EKC algorithms accepting the top six journals are Ecological Economics, Energy Policy, Energy Economics, World Development, Journal of Economic Environment and Management, and, Renewable and Sustainable Energy Review. These journals are published under the Elsevier publishing agency. Apart from the top five journals one journal from Oxford Academic named the Quarterly Journal of Economics, the American Economic Review journal published by American Economic Association, and Environment and Development Economics is one of the Journals of Cambridge core journals are contributing in the publishing studies are in a cloud of environment Kuznets curve. Published studies in the top two journals have played a key role in EKC, which also increases the citation of journals.
(3) Environmental degradation in these countries, China, Australia, France, Spain, Italy, England, Japan, Pakistan, and Malaysia, is running in parallel with the economy. Apart from these countries, the Node of the USA has a different color which connotes that the USA in early-stage has controlled environmental degradation, where green energy consumption for economic growth was considered at an early stage.
(4) Considering the visualization of authors' contribution in the research field of EKC found most influential authors including Prof. Dr. Muhammad Shahbaz from Beijing Institute of Technology, China; Prof. Dr. Ilhan Ozturk from Cag University, Turkey; Usama Al-Mulali from Multimedia University, Malaysia. From the Prestol University Kohot Islamabad, Pakistan Prof. Dr. Khalid Zaman, and Some are Chinese professor Dr. Zhaohua Wang, Dr. Kangyin Dong, and Dr. Shaojian Wang Who is working at Beijing Institute Technology China, Rutgers University-New Jersey, Sun Yat-sen University China is actively contributing.
(5) Concerning keywords and categories are merged in four clouds, environment science, business and economics, green and sustainable technology, and energy. Environmental

science includes EKC, pollutions, and emissions that occurred by different sources. Business and economics knew as per capita income, economic growth, FDI and international trade. Energy is the source of power includes petrol, diesel, and other burning oils which ultimately lead to having a significant influence on the environment. The cloud algorithm of green and sustainable technology sciences gives a new pathway of research to authors for further investigation.

Therefore, this study recommends that scholars pay more attention to green and sustainable energy technology for further research to reduce the carbon footprint from the environment with sustainable economic growth. In the future, each cluster as topic selection word can be analyzed and more analysis such as earth maps and visualization trees can be presented using bibliometrics.

Limitations of the study

Although this research has demonstrated the best module of EKC visualization for better understanding and clear the research trend for future perspective. Still, this research has some limitations which need to be considered in the future study. While data collection just environmental Kuznets curve (EKC) word was searched in the topic rather to title in the web of science. This study just selected those articles which were published in SCI, SSCI, and SCIE indexing core journals, this study didn't select those articles which are published in non-SCI, SSCI or SCIE core journals. Bibliometric analysis is a very substantial research visualization. Therefore, this study just covered the important visualization still in the future need to investigate the concept tree for EKC, Google earth map visualization, and clustering of each node.

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Ethical Approval
This manuscript all the authors has checked and agreed to publish into ESPR.

Consent to Participate
This article paper used the secondary data collected from the web of science, in this study there is no involvement of human being nor any animal.

Consent to publish
Authors are well aware and sure that used data in this study is not previously published.

Authors' contribution
Koondhar M.A., ideologically generate the ideas and draft the manuscript, Shahbaz M contributed in data collection and visualization. Memon K.A., helped to check the visualized results and revised the manuscript. Ozturk I., contributed in proofreading and give valuable comments. This study was done under the supervision and funded by the Rong K.,

Competing Interests
All the authors declared there is no competing of the interest.

Availability of data and materials
Secondary data for this study was gathered from web of science, data can be provided on request.

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