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Review article

# A bibliometric review analysis into environmental kuznets curve phenomenon: A retrospect and future direction

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ABSTRACT

The present study presents a retrospect into environmental Kuznets curve hypothesis (EKC). The EKC debate is dated over four decade long and worthy of empirical scrutiny. To this end, the present study leverages on over 200 previous studies curated from SCOPUS and Web of science (WOS) core collection database respectively. The present study also presented both literature schematic on the evolution, trends, gaps, and future directions on the EKC debate. This paper endeavors to enhance our comprehension of the inherent paradoxes present in sustainability discourses by delving into the fundamental assumptions underlying the Environmental Kuznets curve (EKC). By conducting a bibliometric analysis, we aim to shed light on the factors contributing to the prominence of thematic keywords within sustainability discourses. This study seeks to provide valuable insights into these dynamics and implications on sustainability debates. Key empirical findings outlines predominant and influential studies and journal outlets on the theme under consideration. The present study bibliometric analysis displays that Ozturk i. with 13 published papers 3153 citations and a link strength of 2, Dogan e. Had 7 papers with 2190 citations with no link strength, Shahbaz. B 7 papers 1347 citations and 1 link strength, Saboori b.7 papers 677 citations 1 strength link and Liu y. 6 papers 582 citations with no link strength. From a policy dimension, the present bibliometric study presents valuable depth on the evolution and development of the EKC phenomenon by identifying's the extant literature leaders, action-step for future studies on environmental sustainability without compromise on economic growth as the EKC theme express the tradeoff between economic growth and environmental degradation. Further insights are rendered in the concluding section.

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## 1. Introduction

To date the earth stands as the sole known celestial body that harbors life and this invaluable biosphere faces an imminent peril [1]. Our biosphere, the cradle of diverse ecosystems and species, confronts an impending peril of unprecedented magnitude, necessitating a rigorous examination of its challenges. Seminal study that tries to ascertain these includes environmental kuznet curve [2]. The environmental Kuznets curve (EKC) hypothesis, predicated upon the prevalent notion of "growth-first, clean-later," has established itself as a well-known paradigm in the domain of environmental economics. This hypothesis serves as a prominent framework for comprehending the intricate dynamics that underlie the interplay between economic progress and the degradation of the natural environment. Renowned scholarly works such as those by Refs. [3,4] have substantially contributed to the dissemination and understanding of this theory.

Until the industrial revolution, people believed that Earth's carbon cycle was in balance. However, as the industrial revolution got going, using fossil fuels significantly increased GHG emissions. To keep up with the ever-increasing need for energy, society has become highly reliant on fossil fuels. Consequently, there is now an inextricable link between a country's GDP per capita and its energy use [5,6]. Increasing GHG emissions are directly related to a growing economy requiring ever more energy to consume. Therefore, economic growth over decades has been achieved at the expense of the environment, contributing to global climate change [7,8].

The pursuit of economic growth can distract governments from their responsibility to protect the environment. The reduction of pollutant emissions is a priority for many international organizations. For instance, COP21 and the Sustainable Development Goals (SDGs) reached the goal of lowering the world's average temperature by 1.5–2° Celsius through limiting pollutant emissions. However, increases in China's $CO_2$ emissions over the past few years have made meeting the country's Kyoto Protocol obligations more challenging [9].

The traditional growth model has had severe ecological problems in the environment, leading to several hypotheses, chiefly the environmental Kuznets curve. The hypothesis suggests that during the initial phases of economic development and national expansion, there is a noticeable increase in environmental degradation due to ecosystem pollution (due to overexploitation of resources for production). However, as the economy expands, efforts are made to counteract this trend by adopting cleaner technologies [10,11]. The phenomenon of environmental degradation in relation to economic growth is commonly referred to as the environmental Kuznets curve (EKC) hypothesis, which posits an inverted U-shaped relationship between the two variables. The aforementioned phenomenon was first recorded by Ref. [12], who proposed a U-shaped relationship between economic growth and income distribution (Income inequality) [13]. discovered an inverted U-shaped association between economic growth and environmental deterioration. However, this relationship isn't as clear and direct as hypothesized – given to varied empirical contradictions noted in the literature.

In order to validate the applicability of Kuznets' theory, which was based on observations limited to specific developed and underdeveloped countries during a particular time period, it is imperative to conduct further empirical surveys across diverse regions and countries, utilizing newly compiled data. This verification process becomes even more crucial considering [14] recent publication refuting the universal validity of Kuznets' hypothesis. The debate surrounding the validity of the Kuznets inverted U-curve hypothesis has seen contrasting viewpoints [15,16]. found evidence in support of the hypothesis using cross-sectional data, while [16,17] did not support it.

In order to elucidate more on the EKC phenomenon (See appendix-Table A1) for a synopsis of most up-to-date review literature on EKC; it compares and contrasts the results of several studies.

Also, there lies significant world events that make the notion of EKC need further assessment –The Russian-Ukrainian conflict has emerged as a catalyst exacerbating the already heightened prices of commodities, encompassing not only energy sources such as oil and gas but also critical industrial metals and agricultural products like wheat and corn, which sustain numerous nations worldwide. Prior to the conflict, commodity prices had already witnessed a sharp surge attributed to the post-COVID-19 pandemic economic recovery. However, the conflict has introduced further complexity into this landscape, albeit with a notable aspect warranting attention: financial markets, reliant on expectations, proactively factor in future risks by anticipating the escalation in commodity prices. As such the trade openness cannot be discounted under the scope of EKC.

Furthermore, it is imperative for a sustainable shift towards green growth cannot be overstated in the context of climate change adaptation and mitigation. Nonetheless, the absence of precise and uniform definitions and a dearth of standardized metrics for assessing green growth has resulted in disagreements concerning its underlying factors. Consequently, this disagreement impedes the capacity to provide policymakers with effective guidance. In this study, we make a significant contribution to the ongoing global discourse on green economic development by critically evaluating previous research on the environmental Kuznets curve (EKC) and identifying persisting limitations. Specifically, we examine the persisting issues associated with the trajectory of economic growth and its environmental tradeoffs, shedding light on crucial areas for improvement.

Notwithstanding numerous evaluations carried out in diverse settings, encompassing economies, time periods, factors, and approaches, a unanimous agreement on the outcomes has yet to be attained. As a result, this survey article aims to answer numerous pressing problems in the field: Are environmental challenges becoming more complicated, and is the EKC keeping up? (ii) What causes the inverted U-shaped curve and what elements contribute to it? and (iii) How can the EKC be improved to more accurately reflect the complex interrelationship between economic growth and environmental damage? To address these issues, previous literature reviews have been conducted, but no meta-analytic or bibliometric approaches have been utilized. Therefore, .this study aims to contribute to the existing literature by conducting a bibliometric -analysis of studies on the environmental Kuznets curve hypothesis.

### 1.1. Origins, conceptual framework, and shape of the EKC

There is an inverted U-shaped link between environmental degradation and per capita income, according to the EKC hypothesis. Kuznets created the EKC in 1955 to analyze the correlation between income per capita and income inequality [18]. As stated by Ref. [19] Simon Kuznets's Nobel-winning framework is based on the economic and social structure of national development processes. When the inverted U-shape was accepted in the field of environmental studies, interest in the EKC grew. Since the pioneering work of [13] the EKC has received considerable attention from policymakers, theorists, and empirical researchers and has begun to be widely employed in environmental studies [6].

## 2. Conceptual framework

The fundamental principle of the EKC hypothesis is the relationship of environmental degradation and economic growth, as well as the negative effects of economic growth on the quality of the environment. According to Ref. [13] there are three stages in the association between economic development and environmental degradation throughout the growth trajectory. These phases are impacted by scale, composition, and technological impacts. When the economy begins to develop it has a scale effect on the environment. According to the EKC theory, at the start of economic growth, urbanization, and industrialization both utilize natural resources and create urban and industrial waste. That is why, at the beginning of economic development, there is a negative association between economic growth and environmental quality [20]. endorse this viewpoint, claiming that pollution grows during the early stages of economic growth since the primary goal is to create wealth and generate additional revenue by increasing output, rather than having clean air or drinking water, etc. As the country's wealth rises, the industrial structure begins to undergo transformative changes, which alters the underlying framework of the economy. At this point, economic development begins to have an environmental composition effect, which is often favorable. During this time, businesses and industries change to using cleaner technology, increasing energy efficiency. This is because environmental quality is becoming more important. In the later stages of development, environmental safety plays a significant role in economic policy and provokes significant concern for the global society. This viewpoint is supported by Ref. [21] who argued that, in the later stages of economic development, there is a substantial rise in income levels, which, in conjunction with an improvement in the quality of institutions, a better understanding of environmental responsibility, and high absorption of innovations and technological advances, results in a reduction in environmental degradation. Hence, at later phases of economic development, both economic growth and environmental quality improve at the same time, and the relationship between them takes the form of a bell-shaped or inverted U-shaped curve (See Fig. 1). This phenomenon is known as the EKC hypothesis.

### 2.1. EKC different specifications

Studies of the EKC hypothesis use a wide variety of approaches, but they all use the same basic framework. Most of these studies rely on time series or panel data, and the model used often looks like this:

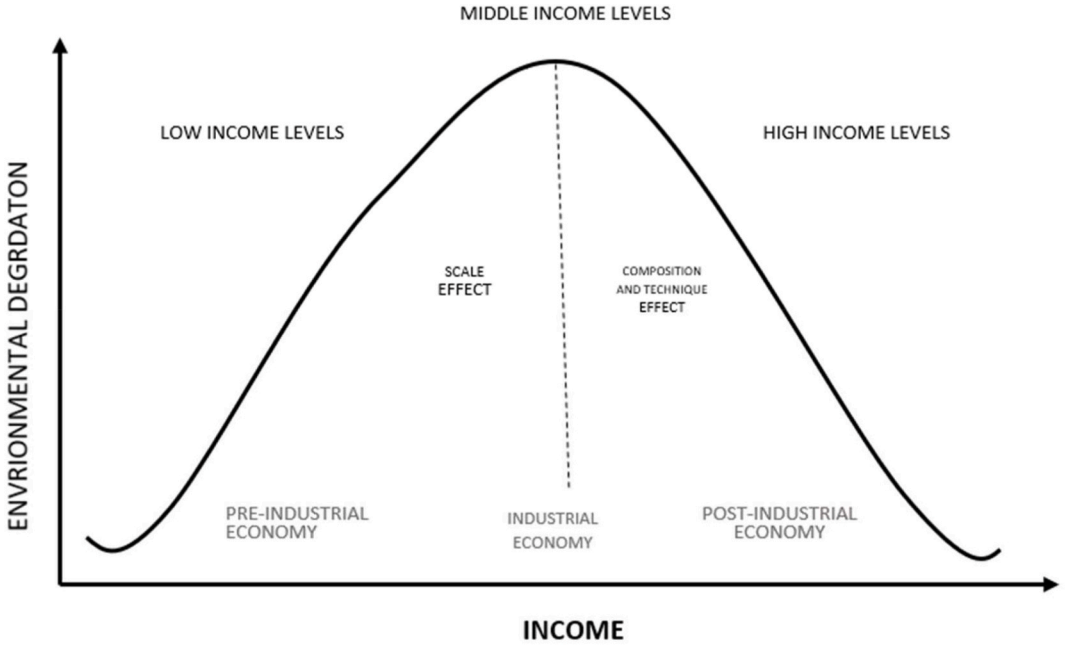


**Fig. 1.** Environmental Kuznets Curve [22].

$$Y_{it} = \sigma_{it} + \gamma_1 X_{it} + \gamma_2 X_{it}^2 + \gamma_3 X_{it}^3 + \gamma_2 D_{it} + \varepsilon_{it} \quad (1)$$

Where Y represents the environmental variable, X represents economic Development, D represents a second independent variable, $\sigma$ represents a constant, $\gamma$ s represents the coefficients in the regression model, and ε represents the standard error. Table 1 summarises the several possible relationships between economic growth and environmental variables that might occur from the model described by Equation (1). The relationship between economic growth and environmental indicators can be represented graphically in Fig. 2a.

## 3. Methods

This study employs three different methodologies. The process begins with a thorough keyword search in the academic database (Scopus) and Web of science (WOS) core collection database to gather the pertinent papers on the EKC. After that, a citation-based analysis based on bibliometric metrics is offered. The content analysis of the articles with high ranks adds to the study's depth. The main components of the approaches employed for each of our paper's objectives are described in this part and are shown in the following subsections.

There are a number of scholarly databases you may use to look for relevant publications on the EKC. These could include, among many others, SCOPUS, Web of Science, ScienceDirect, ProQuest, and Business Sources. The usage of SCOPUS and Web of Science among these databases is useful since they include thorough bibliometric details for each paper, including TC, APY, references, the funding institution, and similar information. Other databases lack this level of information, which is necessary to carry out citation-based studies.

### 3.1. Core objective

In order to establish the research topic and specify the goals of the study's scope, the bibliometric analysis used in this study begins with the issue description. A thorough examination of the body of material that already exists on the EKC hypothesis is attempted in this research. Maps were produced based on network data extracted from scopus on prevailing scientific publications, scientific journals, authors contributions, the impact of study findings by countries, the impact of literature by journals, prevalent keywords, citations are tallied, and text corpus to achieve the study's objective.

### 3.2. Data collection and preprocessing

The process of locating relevant data involved the identification of search phrases, which played a critical role. While several of these phrases aimed to capture similar concepts, there were instances of ambiguity and arbitrary selection of terminology. Nonetheless, because to our multidisciplinary approach, we were able to address the main concerns without being diverted by superfluous words. The Social Sciences Citation Index will be used to conduct the bibliometric analysis.

Several prominent online academic databases, including Google Scholar, Web of Science, and Scopus, are widely recognized [23]. It should be noted that Google Scholar's database, which relies on automated retrieval, may result in the loss of crucial information from certain publications [24]. As a result, the utilization of data obtained from the Google Scholar database was deemed impractical. Conversely, Scopus, which contains approximately 80 % of the data excluded from the google scholar database for this study, emerged as a viable alternative. Moreover [25], emphasize that Scopus is the largest academic citations and abstracts database worldwide, offering an extensive and comprehensive range of sources. Consequently, Scopus was chosen as the preferred database for this research.

Our query Search.

Our initiate search query offered a plethora.

TITLE-ABS-KEY ("Environment Kuznets Curve" OR "EKC hypothesis" OR "EKC " OR "China EKC" AND "trade" OR "trade openness" OR "trade liberalization" OR "China trade openness" OR "China trade " OR "China trade Liberalization") AND (EXCLUDE (PUBYEAR, 2023) OR EXCLUDE (PUBYEAR, 2001) OR EXCLUDE (PUBYEAR, 1999) OR EXCLUDE (PUBYEAR, 1998) OR EXCLUDE (PUBYEAR, 1997) OR EXCLUDE (PUBYEAR, 1996).

Author(s), document title, year, source title, volume, issue, pages, citation count, abstract, and bibliographic information were among the details that made up the chosen data. The possible publications are subsequently retrieved as text files with the extension

**Table 1**
8 forms of assocation betweeen envrionmtmental degradation and economic growth.

| Type of association between X and Y variable | $\gamma_1$ | $\gamma_2$ | $\gamma_3$ |
|---|---|---|---|
| Inverted U-Shaped | + | − | Zero |
| *N*-Shaped | + | − | + |
| U-Shaped | − | + | Zero |
| Inverted U-shaped | + | − | Zero |
| Inverted *N*-Shaped | − | + | − |
| No Relationship | Zero | Zero | Zero |
| Negative Monotonic | − | Zero | Zero |
| Positive Monotonic | + | Zero | Zero |

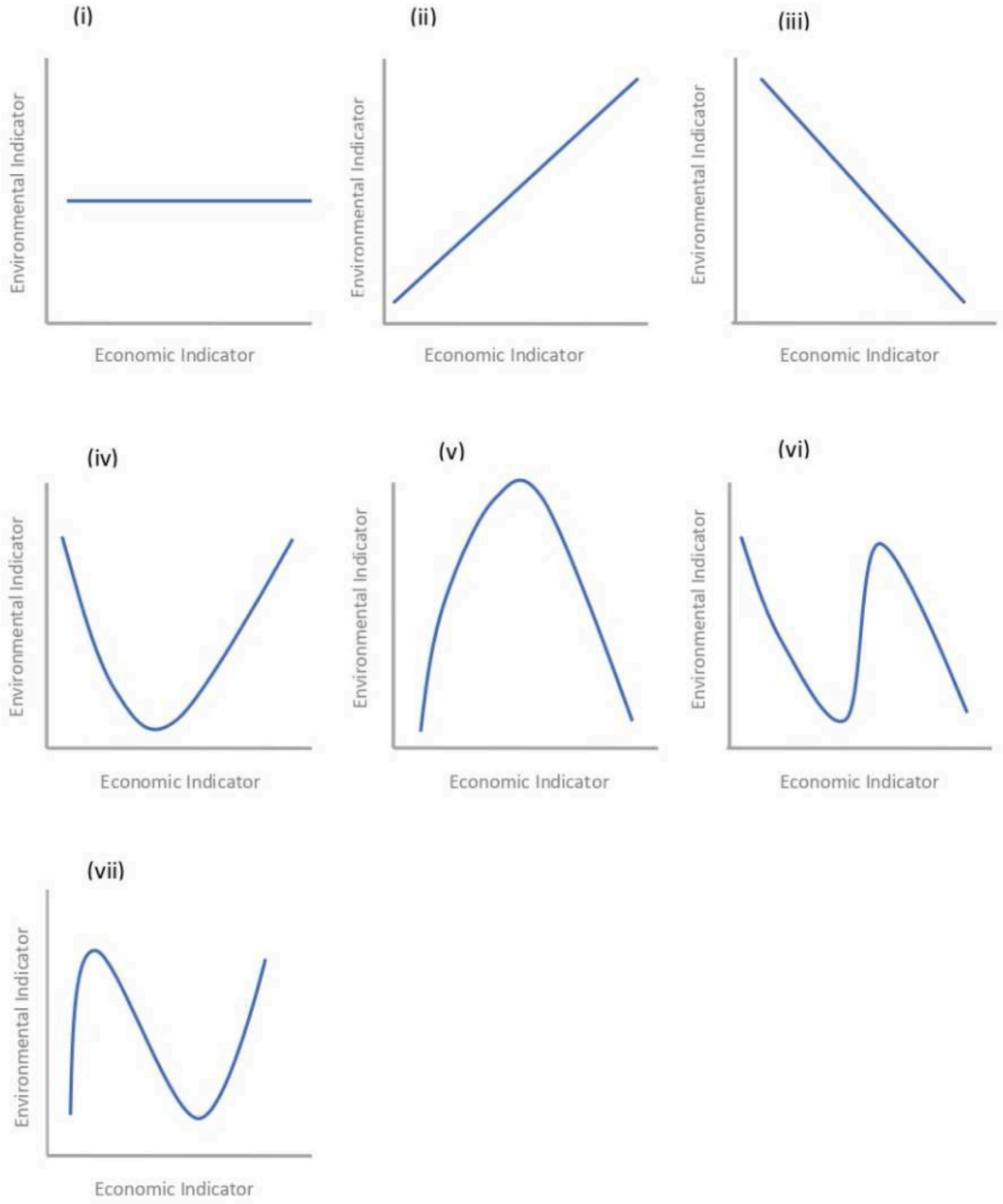


**Fig. 2a.** depicts forms of EKC. Legend: (i) No relationship (ii) Positive (iii) Decreasing (iv) U-shaped (v) Inverted U-shaped (vi) Inverted *N*-shaped and (vii) *N*-shaped association between x and y [18].

"txt" for further examination and synthesis using bibliometric analysis and an inductive technique to iteratively improve the evaluation framework. The retrieved data was then utilized to generate visual maps using the VOSviewer program [26] and the "bibliometrix" R-package [27].

## 4. Results

The results of an empirical study of 949 papers and 23,165 references are presented in this section. Additionally, it examines the many studies that affect how EKC is defined as a knowledge domain (such as co-citations, journals, and institutions). Examining article co-citations makes it easier to pinpoint the connections between scholars and their work over a certain period. As EKC has been a growing theme due to the need to achieve various environmental concerns such as carbon neutrality set by China, the 2030 Climate Target Plan by EU, and net zero emissions by USA. Therefore there is need to keep track of all studies to better streamline policy.

Therefore this study identifies extremely significant academic publications that have the potential to alter the way the EKC is thought of as a knowledge domain. The study incorporates micro- and macro-level dynamics, which further enhances comprehension of the build of any knowledge domain. It also includes burst detection to make it easier to observe impending research fronts. It further shows any possible knowledge gaps which inform academia on what next could be done to further broaden the concept of EKC and deal with the main ailment of promoting green grown and promoting environmental good.

Specifically in Fig. 2b, the annual scientific output is shown. This statistic shows that, there has been a flatuation thread with the growth of publication on EKC, the overall number of publications (2000–2022). The complementary Fig. 3 results also show a growth decline −3.41 %. The total number of 949 authours has contributed to 432 document publication within the last two decades. A less interesting phenomenom is the low international collaboration, which has a percental rate of 36.81 %. which totals 23,164 references. There might be a number of causes for this high citation. This might be attributed to the ensuing "energy and growth" discussion, which encouraged scholars to look at the connection between GDP development and environmental pollution using the EKC paradigm. For instance, towards the beginning of 2010, researchers may have begun paying greater attention to environmental damage brought on by industrial development or deforestation (for more information, see Ref. [28]. This is currently his highest cited published paper with over 1960 citations and [4] who also have this hghest paper-which has also generated 960 citations [4,28–31,32]. are papers on EKC which ascertain a similar pattern in the development of publication numbers connected to the energy-growth nexus. Additionally, a common venue for disseminating information, such as conferences and workshops regarding the energy-growth nexus, has raised awareness within the scientific community internationally, leading to a continued interest in EKC within literature. Additionally, the Paris Agreement and the sustainability objectives it encouraged the majority of signatory nations to adopt have pushed scholars to do greater study on the numerous environmental challenges and the corresponding economic sectors and processes.

### 4.1. Author-document citation relationship

To construct a map based on citation data, author-citation analysis was done using the "author(s)" unit from the downloaded data. The default setup, which uses the entire counting technique and a threshold minimum of 5 documents per documents, was left alone; 12 of the 949 documents fit the criteria, and their results are provided below. Table 2 The amount of citation linkages for each of the 12 writers is determined, and the authors with the most connections are chosen using the linlog/modularity normalization approach using citations as an option for weights in the visualization scale. The top 12 authors who have written on EKC hypothesis are shown in Table 2 for brevity, Ozturk i. 13 papers 3153 citations and a link strength of 2, Dogan e. Had 7 papers with 2190 citations with no link strength, Shahbaz. B 7 papers 1347 citations and 1 link strength, Saboori b.7 papers 677 citations 1 strength link and Liu y.6 papers 582 citations with no link strength as highlighted in Table 2.

There is a common misconception that more paper publication results in more citations; however, this study proves otherwise. A specific example is Dogan with 7 papers, has more citations than Zaman, with 9 documents, with a difference totalling (1896) and 850 more than Shabaz, with the same number of documents. Many of such distinction is evidenced in the table below. While research cooperation may increase an author's output of scientific papers, an observation from Table 3's total link strength suggests that the influence of those publications on subsequent citations may not be affected. In comparison to original research studies, authors who conducted extensive literature reviews on the EKC hypothesis (such as Ozturk, Dogan, Shahbaz, and others) received more citations. Also notable are the numerous high citations on the theme of EKC. It demonstrates policymakers' concern about this particular theme, whether due to contradiction or persistent environmental issues that necessitate ongoing work on the EKC. Though recommendable, it raises questions about when a conclusion on this particular theme can be reached. Fig. 4 demonstrates this further.

### 4.2. Top publishing outlets for EKC studies

The 1934 Bradford rule states that each discipline's research may be split into zones with about equal numbers of publications to determine the core and supplementary journals that publish those papers. Scientific journals may be separated into a core of periodicals more specifically dedicated to the topic and many groups or zones that include the same articles as the core if they are ordered

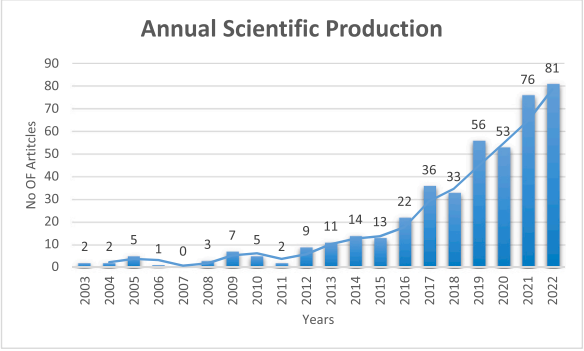


**Fig. 2b.** –Annual scientific Publication.


**Fig. 3.** Graphical representation of data for bibliometric analysis.

**Table 2**
Top most cited authors on the EKC hypothesis.

| Authors | Documents | Citations | Total Link Strength |
|---|---|---|---|
| Ozturk i. | 13 | 3153 | 2 |
| Dogan e. | 7 | 2197 | 0 |
| Shahbaz. B | 7 | 1347 | 1 |
| Saboori b. | 7 | 677 | 1 |
| Liu y. | 6 | 582 | 0 |
| Ahmad m | 6 | 381 | 1 |
| Zaman K | 9 | 301 | 1 |
| Bekun F·V. | 6 | 267 | 0 |
| Murshed M | 5 | 259 | 1 |
| Mahmood H. | 7 | 216 | 1 |
| Udeagha M.C. | 6 | 119 | 5 |
| Ngepah N. | 5 | 104 | 5 |

**Table 3**
Top Journals with publication on EKC.

| Journals | Rank | Freq | cumFreq | Zone |
|---|---|---|---|---|
| Environmental science and pollution research | 1 | 113 | 113 | Zone 1 |
| Sustainability (switzerland) | 2 | 16 | 129 | Zone 1 |
| International journal of energy economics and policy | 3 | 13 | 142 | Zone 1 |
| Energy policy | 4 | 12 | 154 | Zone 1 |

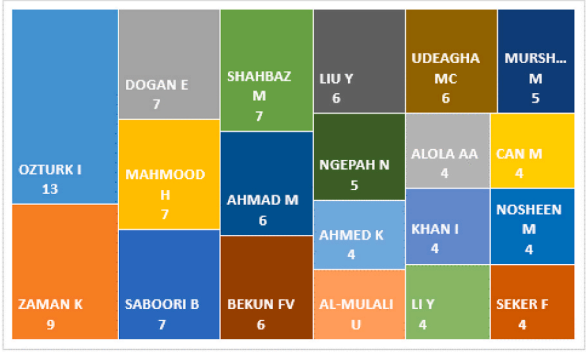


**Fig. 4.** Publication by source authours [constructed with scopus data].

in order of decreasing production of articles on the subject at hand here EKC, according to the legislation.

Following the analysis, the study added three-zone segments. However, for the sake of efficiency, only the zone 1 table is reported, as illustrated in Table 3 Fig. 5 is a complement, which provides a more comprehensive understanding of the various zones into which each journal falls, the core zone (zone 1) is made up of four journals, which account for 36 % of all citations when compared to zone two.

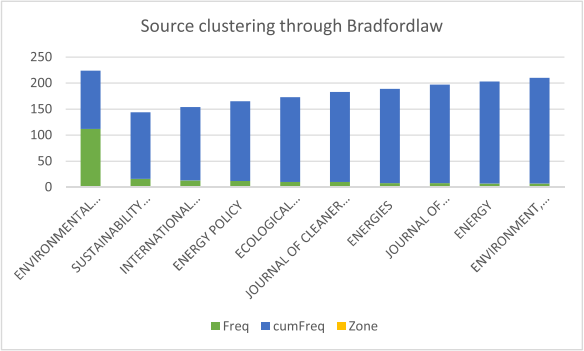


**Fig. 5.** Bradfordlaw outputs.

Fig. 6 depicts a more detailed account of the journals that led to the story of EKC. Source article analysis was performed using the "source(s)" unit from the downloaded data and the top 20 journals that have published articles on the EKC hypothesis in order to construct a map based on citation data. Fig. 6 depicts a treemap of journal publications on the environmental Kuznets curve theory. The top 5 journals that published articles on the theory were environmental science and pollution research (113), sustainability (16), international journal of energy and economics policy (13) and energy policy (12), and ecological indicators (10). If one looks closely, you'll notice that environmental science and pollution research have far more papers than the other 20 journals combined. Contrary to assertions that the idea has received significant attention, it appears that writing on the environmental Kuznets curve has been irregular.

### *4.2.1. Country scientific production*

Another significant aspect to be considered in this article pertains to the comparative evaluation of scientific output among various countries in the context of the environmental Kuznets curve (EKC) development. The study findings shed light on the noteworthy contributions made by academics hailing from four distinct nations, specifically the China, Turkey, Pakistan, Malaysia and Saudi Arabia, who have played a pivotal role in shaping the advancements in EKC. China emerges as the most prolific contributor, with 224 articles published, followed by Turkey with 128 and Pakistan with 99. These statistics unequivocally demonstrate the significant influence that scholars from these countries have had in driving progress in the field of EKC research.

In order to provide a visual representation of the research landscape on a global scale, Fig. 7 presents a captivating depiction of the distribution of research activities across the world. This graphical representation, resembling a treemap, effectively captures the geographical spread of scientific endeavors focused on the EKC. It visually reinforces the dominant presence of the aforementioned countries, as indicated by their higher publication counts, while simultaneously highlighting the comparative absence of significant contributions from numerous developing nations.

It is worth noting that the data provided by this study serve as an important indicator of the research gap prevalent among many developing countries when it comes to EKC investigation. The findings underscore a significant disparity in the level of involvement and engagement within this particular research domain. This calls attention to the need for enhanced research efforts and resources in these regions to bridge the gap and promote a more balanced and inclusive approach to understanding and addressing environmental challenges within the framework of the EKC.

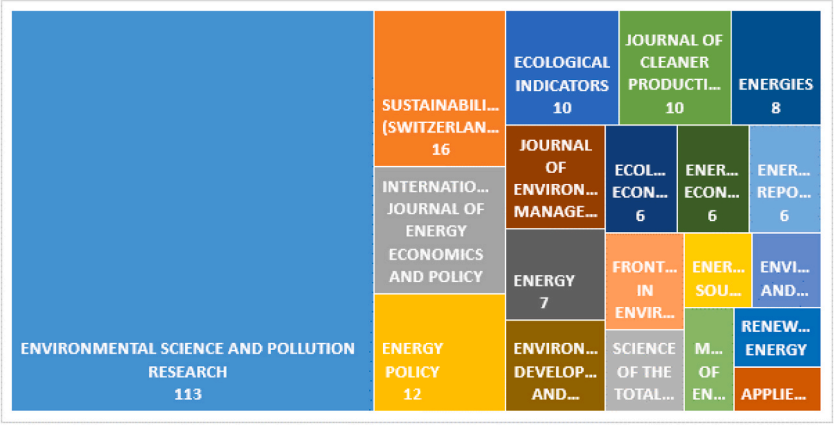


**Fig. 6.** Publication by sources journal [constructed with scopus data ].

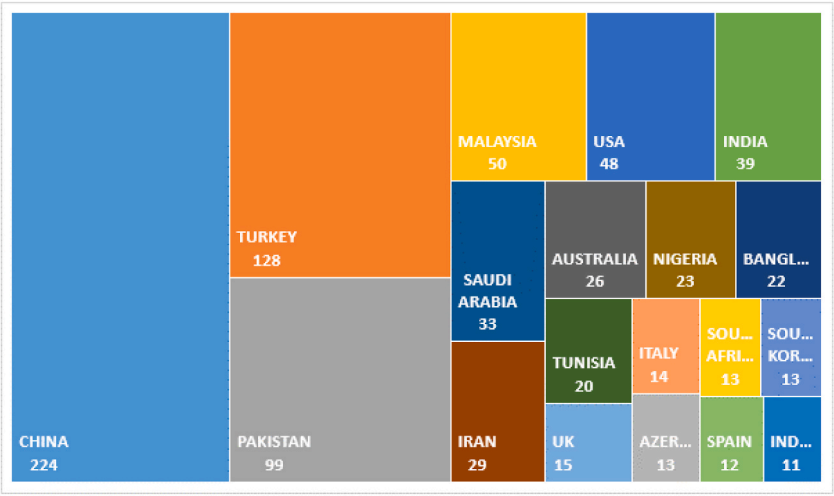


**Fig. 7.** Publication by source countries [constructed with scopus data].

*4.2.2. Country corresponding details*

The affiliation of at least one article author was used to evaluate various categories of scientific collaboration. In the face of the global threat of environmental deterioration, the overall proportion of cooperation shows less teamwork. About 349 people out of a total of 949 collaborated to investigate EKC-related concerns. Table 4 lists the top 20 most productive countries with authors who have contributed to these discussions. There are six European countries, six Asian countries, three African countries, three American countries, and one Australian country. China was ranked first based on its 82 document production, which accounts for 40.96 % of total output. Table 3 shows that research on the EKC theory from low-middle and low-income countries is intermittent and limited.

*4.2.3. Temporal analysis of the most frequent keywords*

Conducting a thorough keyword analysis is critical for gaining valuable insights into the field's evolving research landscape.

*4.2.4. Keywords analysis, co-occurrence network, and trend topics*

Determining the predominant study fields in EKC necessitates a meticulous examination of the frequently employed keywords that encapsulate the central content of articles. This analysis serves as a valuable indicator of the subject matters that garner consistent attention from researchers, thereby presenting potential avenues for novel research inquiries. By delving into the Keywords Plus and Author's Keywords, we were able to identify specific words and phrases that researchers actively employ when investigating the EKC theme. This enabled us to discern the underlying research trends and identify potential areas of further exploration. Additionally, it shed light on any emerging topics or novel dimensions that researchers have started exploring, which have originated from their

**Table 4**
Scientific collaboration between countries.

| Country | Articles | SCP | MCP | Freq | MCP_Ratio |
|---|---|---|---|---|---|
| CHINA | 82 | 49 | 33 | 0.19 | 0.402 |
| TURKEY | 45 | 38 | 7 | 0.104 | 0.156 |
| PAKISTAN | 32 | 16 | 16 | 0.074 | 0.5 |
| USA | 21 | 17 | 4 | 0.049 | 0.19 |
| INDIA | 20 | 16 | 4 | 0.046 | 0.2 |
| MALAYSIA | 15 | 11 | 4 | 0.035 | 0.267 |
| SAUDI ARABIA | 12 | 3 | 9 | 0.028 | 0.75 |
| IRAN | 11 | 8 | 3 | 0.025 | 0.273 |
| AUSTRALIA | 9 | 6 | 3 | 0.021 | 0.333 |
| BANGLADESH | 9 | 3 | 6 | 0.021 | 0.667 |
| SOUTH AFRICA | 9 | 9 | 0 | 0.021 | 0 |
| TUNISIA | 8 | 3 | 5 | 0.019 | 0.625 |
| KOREA | 7 | 5 | 2 | 0.016 | 0.286 |
| NIGERIA | 7 | 3 | 4 | 0.016 | 0.571 |
| ITALY | 6 | 5 | 1 | 0.014 | 0.167 |
| NORWAY | 5 | 0 | 5 | 0.012 | 1 |
| SPAIN | 5 | 2 | 3 | 0.012 | 0.6 |
| SWEDEN | 5 | 1 | 4 | 0.012 | 0.8 |
| CANADA | 4 | 2 | 2 | 0.009 | 0.5 |
| INDONESIA | 4 | 2 | 2 | 0.009 | 0.5 |

engagement with the EKC framework.

Furthermore, we gained deeper insights into the evolving research trajectory within the EKC domain by closely examining the thematic landscape via the Keywords Plus and Author's Keywords. This in-depth examination allowed us to determine the extent to which researchers have broadened their focus beyond the core EKC concept, exploring related themes and branching out into new research avenues. A close examination of the word treemap reveals a significant amount of scholarly interest converging on the interaction between carbon emissions and trade openness, emphasizing its central importance within the discipline. To name a few, keywords plus include carbon emissions, economic growth, the Kuznet curve, environmental economics, international trade, trade-environmental relations, sustainable development, and China, to name a few, while keywords authors include renewable energy, environmental sustainability, environmental degradation, energy consumption, EKC, trade $CO_2$ emissions, trade openness, and financial development. Furthermore Fig. 8 outlines the scatter plot of most related keywords.

*4.2.5. Theme development leading to business strategy and environment*

Fig. 5 presents four distinct thematic typologies visualized through thematic mapping [33]. Thematic mapping utilizes the keyword plus field and employs conceptual structure network and keyword co-occurrence analysis to reveal thematic networks. These networks are traced using a two-dimensional matrix, assessing centrality and density measures. The density, depicted on the vertical axis in Fig. 5, represents the proportion of existing edges to potential edges between clusters of nodes. Centrality measures the connectivity between nodes. Thematic maps display network clusters within each plot, labeled based on the highest occurrence value. The bibliometric analysis identified four thematic areas: niche themes, emerging themes, motor themes, and basic themes, representing distinct research focuses within the field commerce, energy utilization and international trade.

**Niche themes:** Positioned in the top left quadrant, this thematic category represents emerging and specialized areas of interest for scholars. Notably, the topic of "Innovation, Russia Federation,Japan" was identified, which pertains to the importance of aligning objectives with environmental policies.

**Motor themes**: Occupying the top right quadrant, these themes form the central focus when exploring the intersection of business strategy and the environment. Key topics within this category encompass "Carbon dioxide, Kuznet Curve". However, it shares boundaries with basic themes.

**Basic themes:** These well-established and commonly studied topics are fundamental to the overarching theme of EKC. Examples include "Carbon dioxide, Kuznet Curve and Carbon emissions" other themes which share boundaries emerging themes-this include.

**Emerging theme**: This category encompasses relatively novel concepts within the field of EKC. Notable emerging concepts include commerce, energy utilization and international trade.

Figs. 9 and 10 offer further themes and decomposition, which authors pay attention to, further explanation will be incorporated in the discussion of 13. Since we use the opportunity to further explain why such a theme could be recurring in literature for EKC.

*4.2.6. Research hotspots in the EKC literature*

The frequency of keywords used in scientific research, as indicated before in the "Data and methodologies" section, aids in identifying the mark of academic material. We discovered that the majority of terms in the EKC literature are unique, despite the fact that a small collection of keywords has been frequently utilized by academics. We developed a co-occurrence network to demonstrate the interaction between academic journals, nations, and keywords after the first consolidation, as indicated in Fig. 11. Through the examination of the co-occurrence network, researchers were able to discern significant patterns, trends, and influential entities within the EKC literature. The network analysis enabled the identification of key academic journals serving as central hubs for EKC research dissemination. Additionally, it sheds light on countries that have actively contributed to the EKC discourse, highlighting their involvement and expertise in the field. Furthermore, the network illuminated the interconnections between specific keywords, offering insights into the thematic coherence and conceptual associations in the EKC literature. On the specific, we can discuss a few key themes.

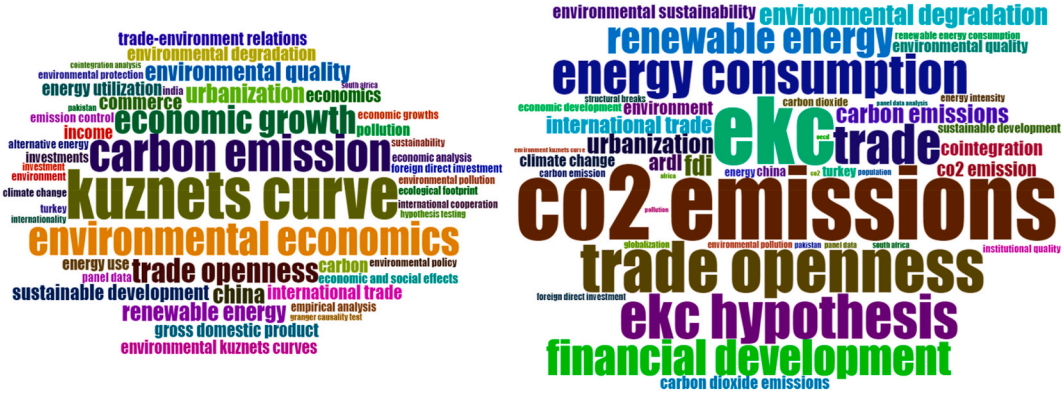


**Fig. 8.** Scatter plot of most related keywords.

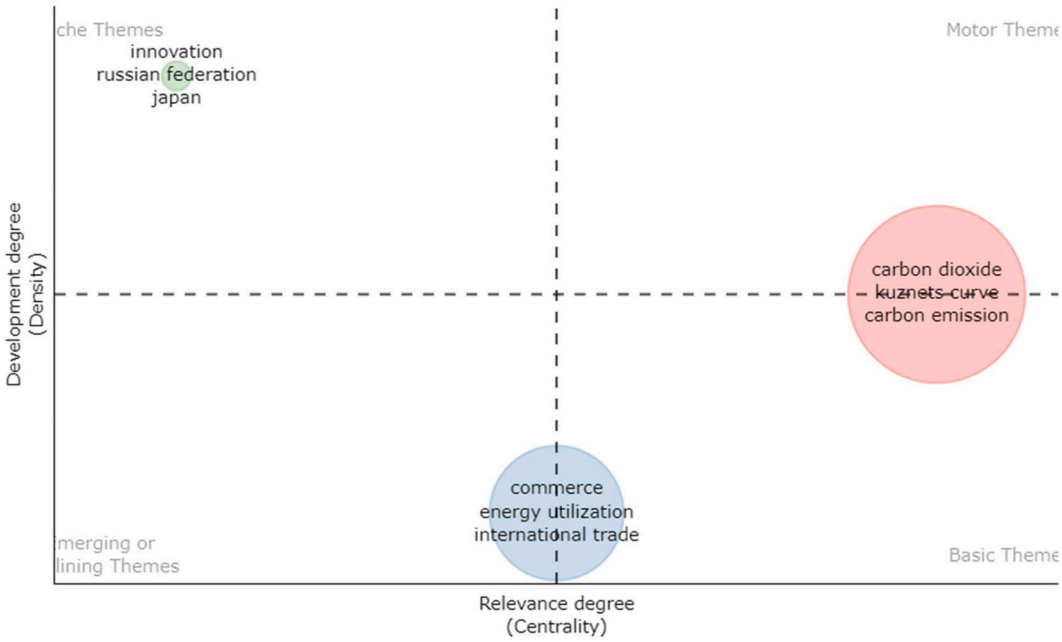


**Fig. 9.** Thematic map.

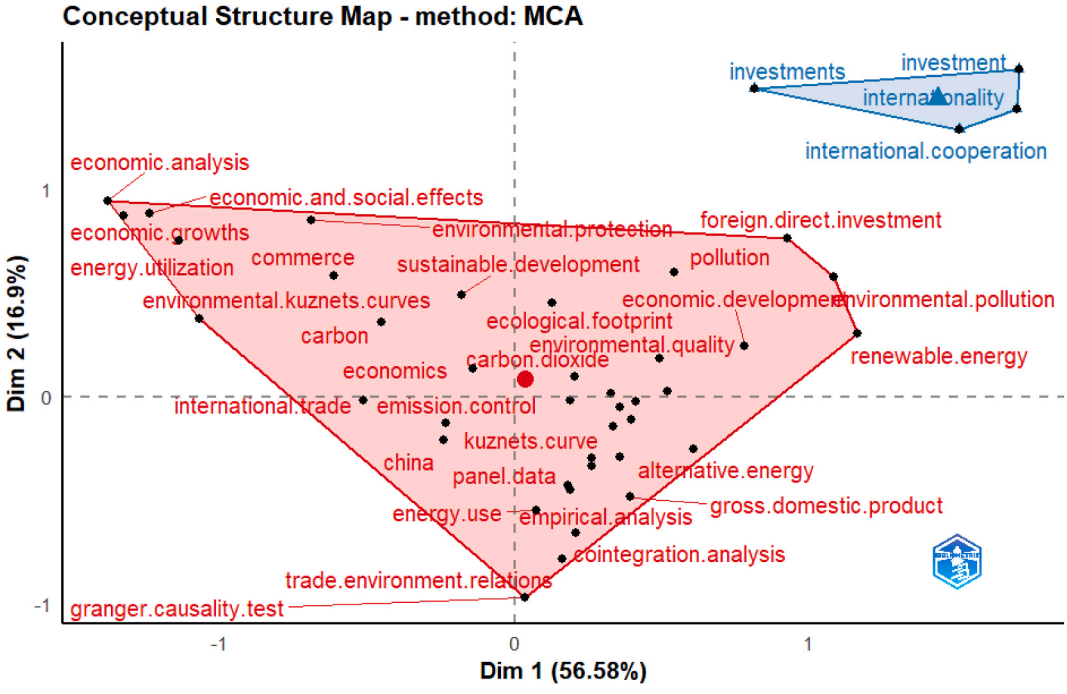


**Fig. 10.** Concpetual structure framework.

*4.2.7. Carbon emission*

Since the early twentieth century, economic reforms have overseen international economies battling for economic resources in order to preserve a competitive edge over one another leading to industry revolution. The industry revolution ties into traditional model of production –which has heavily relied on dirty fuel predominantly fossil fuel. Raising concern for future generation-concerns include cliate change, global warming, rising sea levels all resultant of excessive pollution from carbon emission – a by product of using fossil fuel. Literature indicates the release of green house gases into the earth's atmosphere is one of the primary drivers of global warming. Several policy initiaitves has been proposed to help minimize the carbon emission and avoid additional environmental

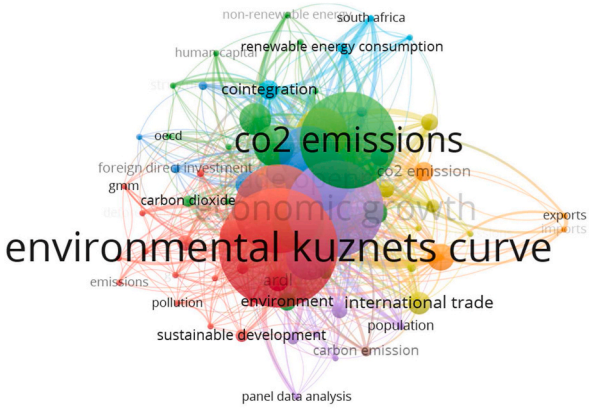


**Fig. 11.** Thematic cocurrent analysis.

devastation. This includes carbon pricing: Imposing a financial cost on carbon emissions encourages the adoption of low-carbon practices and technologies [30,34]. Another approach is throught renewable portfolio standards (RPS): Mandating a minimum percentage of renewable energy promotes the use of clean energy sources, reducing reliance on fossil. Complementing the RPS is energy efficiency standards: Establishing minimum efficiency requirements for products and infrastructure reduces energy consumption and lowers carbon emissions [32,35–37]. There is also initiaitves for subsidies and incentives for clean technologies: Financial support encourages the adoption of clean technologies like solar panels and electric vehicles [38–40] also there is a need for research and development funding: Investment in R&D accelerates the development of innovative clean energy solutions. International agreements and targets [41]: Global cooperation and commitments, such as the Paris Agreement, foster collective action to address climate change [42,43,44].

#### *4.2.8. Economic growth*

Until recent decades, the focus of growth theory has primarily been on analyzing growth patterns and the influence of government policies on growth rates [23,45]. However, little attention has been given to the connection between economic growth and the environment. The prevailing growth theory is characterized by a bias as it fails to consider the environmental costs associated with economic growth [46,47]. However, in recent decades, significant research has been conducted to investigate the connections between economic growth and the environment. This research particularly focuses on the implications of natural resources for growth processes and sustainability leading to the discovery of EKC [4,5,48–51]. Nevertheless, novel approaches such as green growth, circular economy, ecological economics, and the SDGs provide frameworks and strategies to reconcile economic development with environmental sustainability, ensuring a more balanced and resilient future [46,52–56]. These approaches promote resource efficiency, renewable energy, sustainable practices, and a holistic perspective on economic development to foster sustainable growth while addressing environmental challenges [46,57–60].

#### *4.2.9. Trade openness*

Safeguarding the environment has evolved as a worldwide priority in recent decades, reflecting broad worries about environmental deterioration [61,62]. In this context, the environmental effect of trade is a developing concern in trade policy [61,63–65]. An increasing array of empirical research have been conducted to study the link between trade openness and environmental quality [61, 66–69]. The problem of environmental contamination is similar in that trade openness is one of the major contributors. According to Refs. [70,71] Click or tap here to enter text. trade openness is essential for the flow of commodities and the increase of economic production. According to Ref. [72] commerce made up one-fifth of the world's GDP in 2019. However, according to Ref. [73] trade-related carbon emissions make up more than a quarter of all carbon emissions worldwide. Through the use of environmentally friendly technology, nations are attempting to balance trade and carbon emissions as a result of the economic globalization trend. A significant problem is how to enhance growth rates via trade openness while reducing emission [74,75]. Due to regional disparities in environmental costs, the impact of trade openness on carbon emissions is yet unclear [76,77].

#### *4.2.10. Renewable energy*

Renewable technologies are regarded as clean sources of energy. When used effectively, they have little to no negative effects on the environment, generate little residual waste. They are sustainable in light of both present and future societal and economic demands [78,79]. As such, the best alternative way to reduce carbon emissions is to switch from using fossil fuels to using renewable energy. However, the proportion of renewable energy consumption in developing nations' total energy consumption is rather low [80,81]. The installation of renewable energy systems will enable the resolution of the current most critical tasks [82–84], such as boosting energy supply dependability and enabling green growth, resolving shortcomings regarding regional energy and water supply; raising the standard of living; ensuring sustainable development of remote regions in desert and mountain zones; and implementing the countries' obligations in terms of fulfilling the international accord of safeguarding the environment [85,86].

#### 4.2.11. Financial development

The significance of financial development lies in its role as a crucial source of financial resources, supporting both environmental and socioeconomic sustainability [53]. Economic growth and financial development are intricately intertwined, as institutional financing provided to private investors can foster long-term economic expansion. A robust financial establishment plays a vital role in facilitating renewable energy initiatives, as financial intermediation is instrumental in enhancing environmental sustainability [46, 33]. Financial growth exerts a substantial influence on energy consumption and institutional quality, leading to a reduction in energy use. Moreover, a stable financial system enables access to financial resources, thereby improving living standards and driving economic growth. A mature financial structure and the availability of financial resources facilitate the development of modern and efficient technologies that are more energy-efficient and environmentally sustainable, consequently mitigating pollution issues [87]. Furthermore, financial development and capital market liberalization foster corporate linkages, stimulate the transfer of green technology through technical divisions, and facilitate research and development within host nations as presented in Fig. 12 schematic graph.

#### 4.2.12. Implication of the study and future trends

This review article holds considerable significance in the analysis of scientific productivity concerning the environmental Kuznets curve (EKC) hypothesis and its implications for future work and policymaking. The comprehensive examination presented herein provides valuable empirical data and insightful information for researchers, policymakers, government officials, and other relevant stakeholders. It facilitates a deeper understanding and recognition of the contributions made by different countries, authors, and specific research themes concerning the interplay EKC and its developing themes. As such, this research effectively elucidates the influence of research productivity across diverse nations and prominently identifies authors who have made notable contributions. The environmental Kuznet Curve (EKC) has been a prominent framework in the field of environmental economics, exploring the relationship between economic Development and environmental degradation.

In recent years, there has been a growing interest in understanding the implications of international trade on the EKC. International trade can influence environmental outcomes through various channels, including the relocation of pollution-intensive industries, technology transfer, and changes in consumption patterns. Several studies have investigated the relationship between trade openness and environmental quality, providing mixed empirical evidence [88,89].

A cursory look at the highly cited papers –each paper seem to have had a novel approach to assessing EKC framework.

Specifically [90] analyze the causal connection between financial development, trade, economic growth, energy consumption, and carbon emissions in Turkey during the period of 1960–2007. His initial work was to ascertain if there is indeed a longterm relation between the variable of interest-which he achieved assessing cointegration. However the results indicated trade and GDP lead to further impairment of the environement. However same wasn't ascertain for financial development. These findings also supported the validity of the environmental Kuznets curve (EKC) hypothesis in the Turkish economy. This means that the level of $CO_2$ emissions initially increased with income until it reached a point of stabilization, after which it declined in Turkey. Additionally, the paper explored the causal relationship between the variables using Granger causality models based on error correction. This was one of the initial paper that tried to assess the role trade plays within the EKC theorem.

[4] conducted a study with the objective of examining EKC in the case of USA with variable of interest being same as Prof Oztudk which just introduction of a new variable urbanization for a period of 1960–2010. He also ascertain a long run relation among variables. His work also agree that financial development had no relationship on environment degradation but interesting it was discovered for the case of USA trade offer an opportunity to improve the environement. Furthermore, the study did not support the validity of the environmental Kuznets curve (EKC) hypothesis for the USA, as real output was found to contribute to environmental improvements, while GDP square increased the levels of gas emissions. The results of the Granger causality test indicated bidirectional causality between $CO_2$ and GDP, $CO_2$ and energy consumption, $CO_2$ and urbanization, GDP and urbanization, and GDP and trade openness. However, no causality was identified between $CO_2$ and trade openness, as well as gas emissions and financial development. Additionally, sufficient evidence supported one-way causality from GDP to energy consumption, from financial development to output, and from urbanization to financial development. Based on the long-run estimates and the Granger causality analysis, it is recommended that the US government consider the importance of trade openness, urbanization, and financial development in controlling GDP levels and pollution. It is also crucial to note that the development of efficient energy policies is likely to contribute to lower $CO_2$ emissions without harming real output.

In addition, our research attempted to identify the most often studied subject when researching the EKC. As a result, this research identifies the hotspot topic beneath EKC, which also acts as a means of learning about less targeted regions. To that end, this analytical approach aided in the identification of prominent academic journals, which included ESPR, Sustainability, energy policy, and ecological indicators, to name a few, countries actively contributing to EKC research, with China leading and prompting the knowledge most less developing countries, particularly Africa, have not done much towards these areas of interest. This could be alluded to because there is still a struggle with economic growth trajectory to pay attention to environmental tradeoffs, and the linkages between particular keywords. The co-occurrence network analysis provided a robust method for studying collaborative networks within the EKC field, providing insights into the structure of scholarly communication, the distribution of research efforts, and the emergence of thematic clusters. As a result, we encourage other future works to pay attention to the themes listed below.

Future research in this area could focus on examining the role of trade policies, such as environmental regulations, carbon pricing mechanisms, and trade agreements, in shaping the environmental impacts of international trade.

Furthermore, the COVID-19 pandemic and the ongoing Russia-Ukraine impasse have introduced additional dimensions to the study of the EKC. The pandemic has had both positive and negative environmental impacts. On the positive side, lockdown measures and

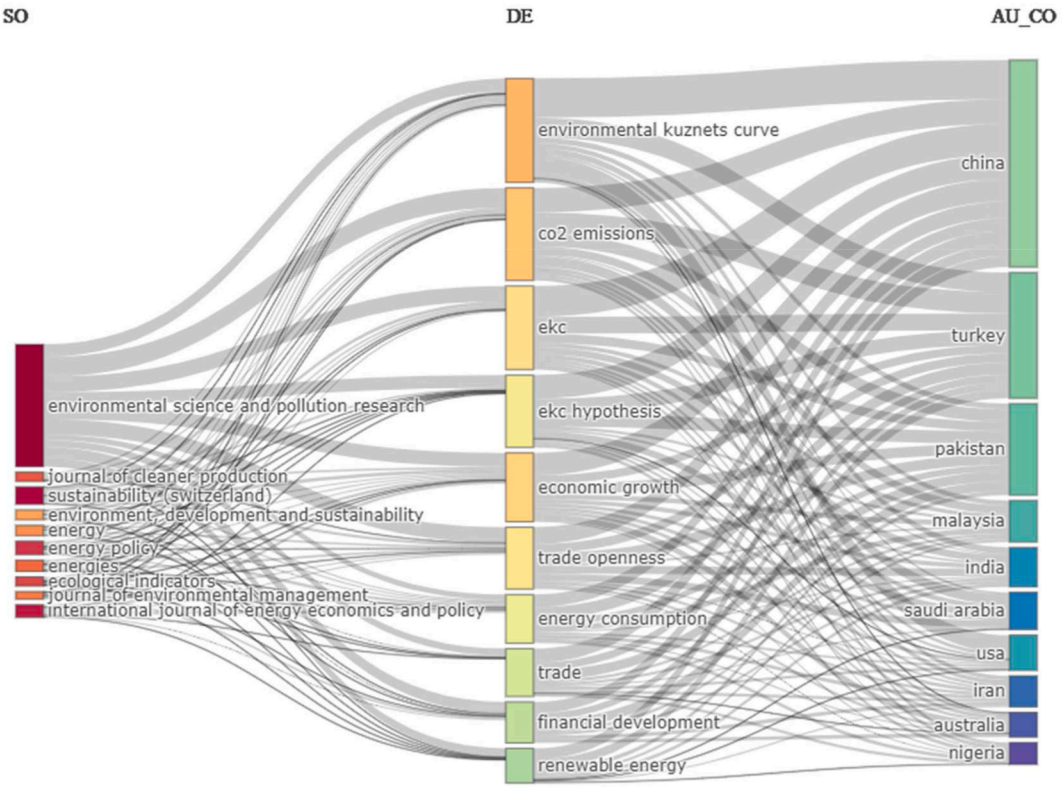


**Fig. 12.** Threefold.

reduced economic activities led to temporary improvements in air quality and reduced carbon emissions. However, the pandemic also disrupted global supply chains, causing shifts in production and consumption patterns that could have long-term implications for environmental sustainability. Future research could explore the lasting effects of the pandemic on the EKC and identify policy interventions to ensure a green and sustainable recovery.

Regarding the Russia-Ukraine impasse, geopolitical tensions and conflicts can have significant environmental consequences. The ongoing crisis between Russia and Ukraine may disrupt regional environmental cooperation, hinder sustainable development efforts, and exacerbate environmental degradation in the affected areas. Future research could analyze the environmental impacts of geopolitical conflicts and propose strategies to mitigate these negative effects. Additionally, understanding the relationship between political instability, economic Development, and environmental sustainability in conflict-affected regions is an important area for further investigation.

In conclusion, future research on the EKC should focus on examining the role of international trade policies, assessing the long-term environmental effects of the COVID-19 pandemic, and analyzing the environmental implications of geopolitical conflicts. By expanding our understanding of these dynamics, policymakers can develop more effective strategies to promote sustainable development and mitigate environmental degradation.

#### *4.2.13. Future trends*

**Integration of EKC with climate change mitigation strategies**: As the urgency to address climate change intensifies, there is a growing need to integrate the EKC framework with climate change mitigation strategies. This could involve exploring the relationship between carbon emissions, economic Development, and policy interventions aimed at reducing greenhouse gas emissions. The integration of the environmental Kuznet curve (EKC) framework with climate change mitigation strategies presents several promising research areas. These include examining the impact of carbon pricing mechanisms on the EKC curve, exploring the role of low-carbon technology adoption in driving sustainable Development within the EKC context, assessing the alignment of policy interventions with sustainable development goals, conducting sector-specific analyses to understand environmental implications and decoupling potential, studying the influence of international cooperation and agreements on the EKC, and evaluating the co-benefits and tradeoffs between climate change mitigation and other sustainability objectives. These research directions can provide valuable insights for policymakers and stakeholders aiming to design effective climate change mitigation policies while considering economic growth and environmental sustainability dynamics.

**Renewable energy transition and EKC**: The shift towards renewable energy sources is gaining momentum worldwide. Future research could investigate the role of renewable energy technologies in accelerating the transition towards sustainable development

and how it relates to the EKC. This could include examining the impact of renewable energy adoption on economic growth, employment, and environmental quality. Examining policy frameworks for promoting renewable energy, and understanding the social acceptance and behavioral aspects related to renewable energy transition. By assessing these factors, researchers can gain insights into how renewable energy adoption can contribute to shaping the EKC trajectory and promoting sustainable Development.

**Circular economy and EKC:** The concept of the circular economy, which focuses on reducing waste and promoting resource efficiency, has gained traction. Research could explore how circular economy practices influence the environmental impact of economic activities and whether they align with the EKC framework. This includes analyzing the potential of circular economy practices to decouple economic growth from environmental degradation, evaluating the environmental performance of circular economy practices through lifecycle assessments, examining the role of circular business models and innovation in driving the transition, assessing the effectiveness of policy frameworks for promoting circular economy practices, and understanding the importance of stakeholder engagement and collaboration in fostering the circular economy within the EKC context. By studying these aspects, researchers can gain insights into how the circular economy can contribute to shaping the EKC trajectory and promoting sustainable Development.

**Technological advancements and EKC**: Rapid advancements in technology, such as artificial intelligence, Internet of Things, and blockchain, have the potential to shape the trajectory of the EKC. Future research could investigate how these technological innovations can be harnessed to achieve sustainable development goals and facilitate the transition to a more environmentally sustainable economy. This connection can be explored through various technical aspects. These include studying the environmental impact of emerging technologies, assessing the role of clean and sustainable technologies in promoting environmental quality, examining how technological innovation can contribute to decoupling economic growth from environmental degradation, analyzing the policy implications and technology transfer, and evaluating potential risks and tradeoffs associated with technological advancements. By investigating these aspects, researchers can gain insights into the impact of technological advancements on the EKC and inform sustainable development strategies and policies.

**EKC in emerging economies:** While the EKC has predominantly been studied in the context of developed economies, there is a growing interest in exploring its applicability to emerging economies. Future research could focus on understanding the unique dynamics of environmental degradation and economic growth in these contexts, and how policy interventions can promote sustainable development. This includes examining different growth pathways, evaluating the effectiveness of policy interventions, considering socio-economic factors and inequality, and assessing the role of technology transfer and innovation.

**Social dimensions of the EKC**: The EKC framework has primarily focused on the economic and environmental dimensions, but there is a need to incorporate social dimensions as well. Future research could examine the social implications of the EKC, including issues related to income inequality, poverty alleviation, and social well-being in the context of sustainable development.

**EKC and policy implications:** Future research could delve into the policy implications of the EKC, including the design and effectiveness of environmental regulations, market-based instruments, and international agreements aimed at promoting sustainable development. This could involve assessing the impact of different policy interventions on the trajectory of the EKC and identifying strategies for policy optimization.

**Interdisciplinary approaches to the EKC:** Given the complexity of the EKC, interdisciplinary approaches are essential to gain a comprehensive understanding of its dynamics. Future research could explore interdisciplinary collaborations, integrating insights from economics, environmental sciences, sociology, and other relevant fields to enhance our understanding of the EKC and its implications for sustainable development. By combining insights from these disciplines, researchers can gain a comprehensive understanding of the relationship between economic development and environmental degradation. This interdisciplinary approach enables the identification of policy interventions, analysis of social factors, examination of technological solutions, and consideration of spatial variations to promote sustainable Development within the context of the EKC.

## 5. Concluding remark and future direction

Environmental policymakers and environmental academics recognize the critical link between environmental deterioration and trade liberalization. Recognizing a deeper scientific knowledge of the severe consequences of environmental degradation on humans and ecosystems is crucial to accomplishing the United Nations SDGs under the 2030 Agenda for Sustainable development. The purpose of this research was to discover the critical links between commerce, and the environment-focused global development objectives. This emphasizes the need of having complete study information on environmental deterioration for establishing future research routes and combating climate change.

This bibliometric evaluation gives a general description and describes the essential environmental degradation and trade features that researchers might use. It also demonstrates the influence of global environmental accords and climate change problems on the pattern of research publishing during the last two decades. Using the bibliographic coupling approach, we identified the most-cited articles, major journals, nations (geographical location), and research organizations (institutions). Most of the figures were presented in tree maps which makes it easy to understand and comprehend for a novice reader.

It seems from the above the EKC will be an unending phenomenom. However with work such as this and provision of new themes to be looked at the issue surround the prominence of this phenomenon could be further reduce leading to green growth.

### *5.1. Bias, limitations, and future research*

Despite its contributions, the study is subject to certain limitations. One inherent limitation of bibliometric methods is their tendency to focus on research outputs rather than content. However, the researchers were able to overcome this limitation by capturing

relevant content in the discussions included in this study. Additionally, there is a possibility of selection bias since the study relied primarily on the scopus as a data source. While the scopus is considered comprehensive and reliable, incorporating additional sources such as web of science, dimension and Google Scholar could provide a more comprehensive understanding of concepts and ideas. Nevertheless, it is anticipated that addressing these limitations would not yield significant deviations from the findings obtained in the current review.

## Additional information

No additional information is available for this paper.

## CRediT authorship contribution statement

**Ajmi Ahdi Noomen:** Conceptualization, Project administration. **Festus Victor Bekun:** Supervision, Validation, Writing – review & editing. **Bright Akwasi Gyamfi:** Data curation, Formal analysis, Investigation, Methodology. **Muhammad Saeed Meo:** Formal analysis, Visualization, Writing – original draft.

## Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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## Appendix

**Table A1**
Latest literature on EKC

| Sr# | Authors | Journal | Number of articles reviewed | Findings |
|---|---|---|---|---|
| 1 | [91] | Environmental Science and Pollution Research | 2384 | This report shows that more effort needs to be put into studying EKC in the context of green and sustainable technology research. |
| 2 | [18] | Heliyon | 200 | The functional specification plays a crucial role in determining whether or not EKC exists. |
| 3 | [92] | Environmental and Sustainability Indicators | 38 | According to the results, the EKC hypothesis is not universally supported in the GCC region. |
| 4 | [93] | Energy Strategy Reviews | 1654 | 62 % of studies affirm the existence of EKC, 29 % confirm the existence of alternative shapes of EKC, and 9 % certify there is no evidence of EKC. |
| 5 | [92] | Environmental and Sustainability Indicators | 38 | The study's findings verified mixed evidences of EKC. |
| 6 | [9] | Sustainability | 117 | The results show that the existence of EKC has been confirmed by 92 out of 112 studies. However, 17 studies did not reach this conclusion. |
| 7 | [94] | Qualitative Research in Financial Markets | 111 | The presence of an environmental Kuznets curve is supported by the vast majority of research. |
| 8 | [95] | Gondwana Research | 2218 | The results show that there is no consensus regarding the threshold, existence, or form of an environmental Kuznets curve. |

Source: authors compilation

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