New trends on Environmental Kuznets Curve research – A bibliometric analysis

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Abstract. Environmental Kuznets Curve (EKC), connecting environmental degradation with income, is established in 1991 from Grossman and Krueger. It comes from the inverted-U shape of the initial Kuznets curve, which described the relationship between economic growth and income inequality. Since then, more than 3,000 scientific documents, examining the relationship between the same independent variable and environmental degradation, have been published. This paper presents a bibliometric analysis of the topic. In recent years, EKC attracts the scientific interest as the number of documents have been continuously increasing. The majority of authors' origin come from China and its affiliation institutes, followed by USA, Turkey, Pakistan, and United Kingdom. The most popular document type is scientific article and the fields in which EKC is most implemented are environmental science, economics, energy, social sciences, and engineering. The most popular keyword of documents are Kuznets Curve, Environmental Kuznets Curve, Economic Growth, Carbon Dioxide and Economic Development.

1 Introduction

Simon Kuznets [1] first examined the relationship between income inequality and economic growth and introduced his homonymous inverted U curve. In his analysis, in the first steps of economic growth income inequality rises gradually and, after reaching a turning point, it starts to decrease, as more wealthier people live in a certain economy.

Considering the above, Grossman and Krueger [2] searched to find a similar relationship between environmental degradation and economic growth. They concluded that the independent variable (usually GDP per capita) first pressures the environment due to the transition from the primary to secondary sector of production. However, after reaching a turning point, that pressure starts to flatten, and then decreases due to the transition to the tertiary sector. Modern technology offers less environmental impacts, which start to decrease, as a consequent of the technique effect and the transition from the secondary to the tertiary sector of production.

Since 1991, Grossman and Krueger's curve is known as Environmental Kuznets Curve (EKC), and attracts the global scientific interest. Except of the above classical inverted U shape, EKC is also confirmed with other shapes such as U, N, inverted N, M, J and inverted C. Figure 1 shows a typical inverted U shape EKC.

The purpose of this study is to present a bibliometric analysis of EKC using various criteria, to record the evolution of this scientific topic. This work is constructed as follow: first, some basic information of the analysis is given; then, the extracted data are set into six categories:

year, type, publication countries, affiliation institutes, scientific field, and keywords, for further analysis. Concluding remarks are put in the last part of the document.
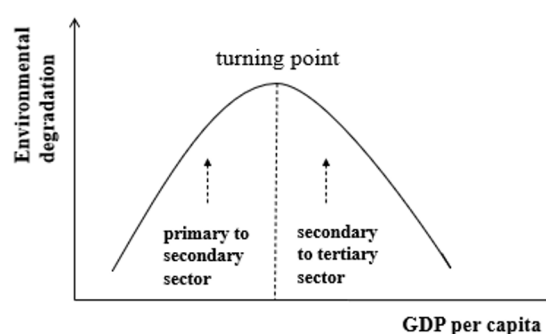

Fig. 1. Inverted U Environmental Kuznets Curve.

2 Methodology and Data

Bibliometric analysis is used "*to unpuck the evolutionary nuances of a specific field, while shedding light on the emerging areas in that field*" [3]. Such analysis is widely used in the literature in several other fields, such as climate change [4, 5], environmental degradation [6], public opinion on environmental issues [7], tobacco products [8] or energy poverty [9].

In this paper, Scopus database was used. The keywords of our search were: "Environmental Kuznets Curve". The entire keywords make a more appropriate

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manner to extract the EKC related documents, as the acronym EKC is also used in biochemistry, genetics, and molecular biology issues (ElectroKinetic Chromatography).

This search results in 3,371 documents published from 1994 to 2023. Limiting in the documents published in English language and extracting those published in trade journals and during the continuously updating current year (2023), the final documents number consists of 3,236 documents during the period from 1994 to 2022.

2.1 Annual and cumulative documents production

Starting from 1994, where the first EKC document was published, Figures 2 and 3 show the annual and cumulative number of documents published. In 1997, more than 10 documents were published, where in 2008 and 2014 the cumulative number was higher than 50 and 100 respectively. During the last five years, the annual productivity is increasingly higher and reaches the number of 225, 327, 349, 449 and 593 documents respectively. From 2016, the total number of published documents was higher than 1,000, when in the two previous years was higher than 2,000 and 3,000 respectively.

2.2 Type of documents

Figure 4 shows that most of the published documents (88%) are scientific articles, the most usual document type in scientific journals. The minority of them is published in other document types, such as conference papers (5%), book chapters (3%), reviews (3%), conference reviews and other (1%). This is expected, as Scopus covers mainly journals; the conferences are coved in a lesser extent.
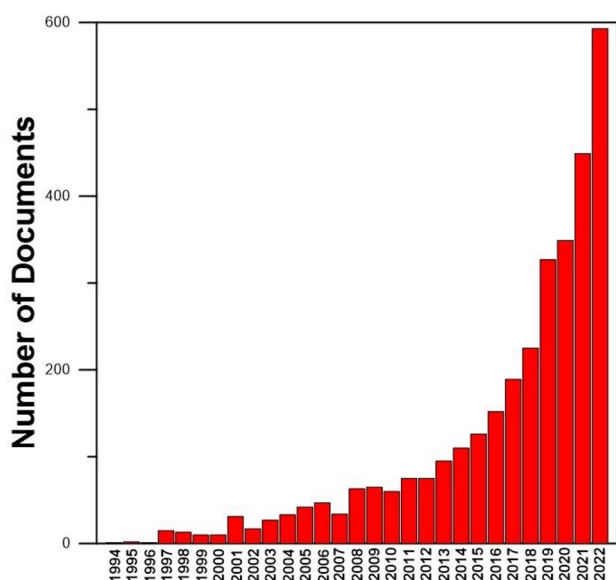

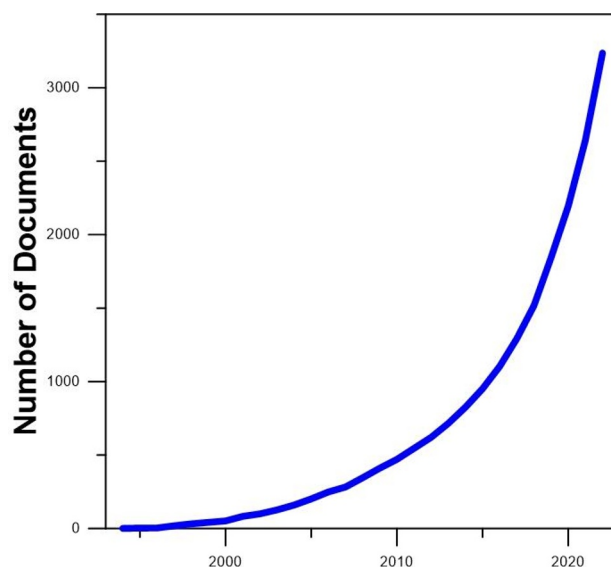**Fig. 2.** Evolution of annual number of EKC documents published.

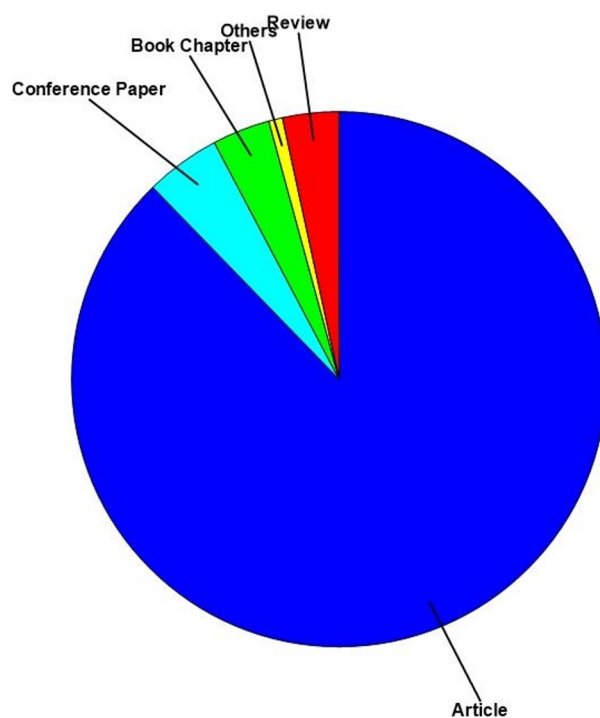**Fig. 3.** Evolution of the cumulative number of EKC documents published.

Fig. 4. EKC documents per type.

2.3 Countries

Even if China started to deal with EKC issues ten years after the first publication, almost the 1/3 (30%) of the total documents have already published from this country. As shown in figures 5 and 6, scientists from the USA are also very productive in this field, as USA it is the country with the second number of documents. However, the relative contribution of USA shows a decreasing trend, as the percentage of those documents is much less during the last three years (5% of the total), compared to the period 1994-2010, when its annual production corresponded to, depending on the year, the 20-60% of the total number of articles.

The following countries are Turkey and Pakistan, with over 300 documents in the total period, showing an increasing trend of their specific weight during the last years. Since 2018, Turkish scientists have published more than 20 documents per year and reached 105 in the previous year (2022). Following Turkey, Pakistan have produced more than 40 documents per year since 2019 and reached its top in 2022, when it published the third highest number of EKC documents (106).

The rest of the top-15 countries are United Kingdom (5%), India (5%), Malaysia (5%), Australia (4), Spain (4%), France (4%), Saudi Arabia (3%), Japan (3%), Italy (3%), Nigeria (2%) and Germany (2%).
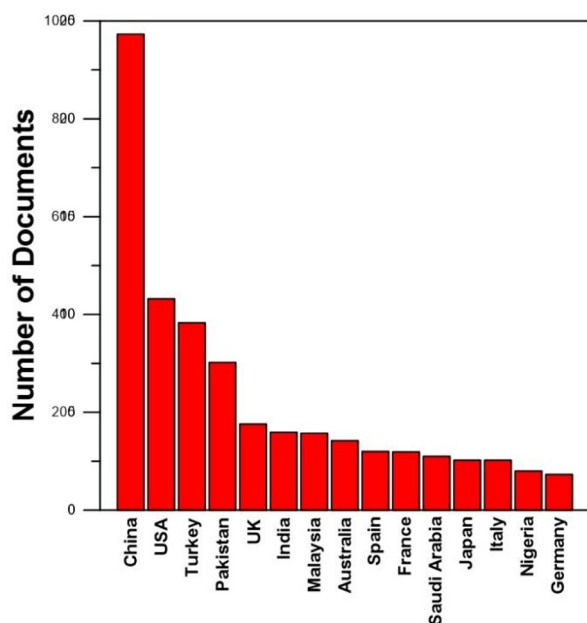

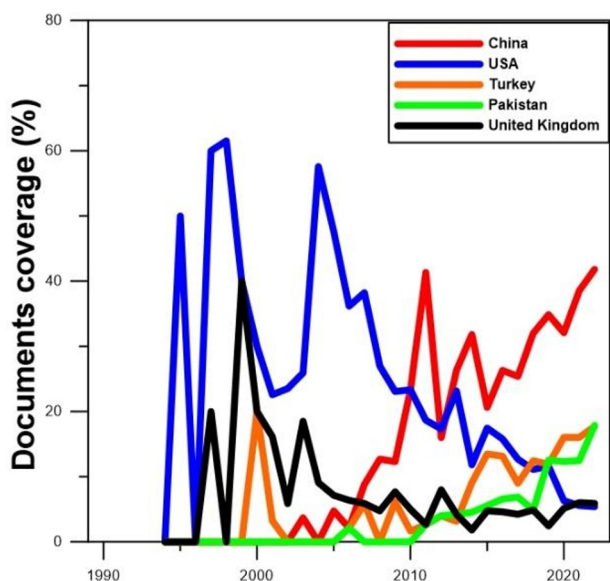**Fig. 5.** Total number of published documents per country

Fig. 6. Evolution of the relative percentage of EKC documents produced per country.

2.4 Affiliation institutes

Taking into consideration the above analysis, the examination of affiliation institutes validates the country

of publication analysis. Four Chinese institutes (Beijing Institute of Technology-BIT, Chinese Academy of Sciences-CAS, Jiangsu University-JU and University of Chinese Academy of Sciences-UCAS) are into the top-10 of total EKC documents productivity.

As Turkey is the third country in total number of EKC publications, there are four Turkish institutes (Eastern Mediterranean University-EMU, Istanbul Gelisim Universitesi-IGU, Cag Universitesi-CU and Isletme ve Ekonomi Fakultesi-IEF) in the top-10 affiliations concerning the total number documents.

The last institutes in the top-10 places come from Spain (Universidad de Castilla-La Mancha-UCLM) and Saudi Arabia (Prince Sattam Bin Abdulaziz University-PSBAU). The above results are shown in Figure 7.
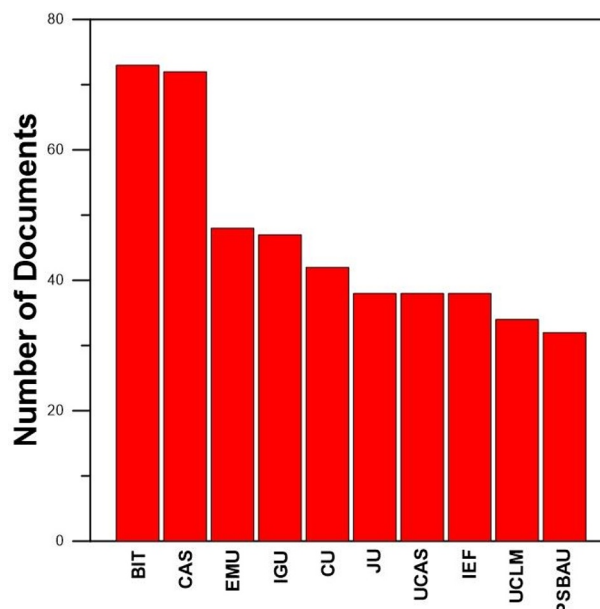

Fig. 7. Total number of documents published per affiliation

2.5 Scientific fields

The results of the bibliometric analysis show that environmental science is the first field in the number of EKC documents published. As shown in figures 8 and 9, more than the 50% of the annual production in the entire examining period is related to that scientific field. Considering the period 1994-2022, the environmental scientific field is contained in 60% of the total productivity. This percentage decreases until 2013, btu increases again since that year.

Economics, econometrics, and finance is the scientific field found in the second place of the total number of published documents. Their specific weight, however, shows a decreasing trend. During the first 10 years period (1994-2003), at least 70% of the total number of documents per year was included in this field; however, is percentage is less than 30% during the last 5 years (2018-2022)

Energy and Social Sciences are found in the third and fourth place with 26% and 23% of the total production. Analysing their evolution during the last 5 years, they show a quite constant coverage of around 30% and 20%

respectively. Engineering is the fifth field with 13% of the total document's number. The higher percentage of this field was in 2014 with 22%; while this percentage is around 15% during the period 2017-2022. The rest of the EKC top-10 scientific field involves Business, Agricultural and Biological Sciences, Mathematics, Earth and Planetary Sciences and Computer Science.
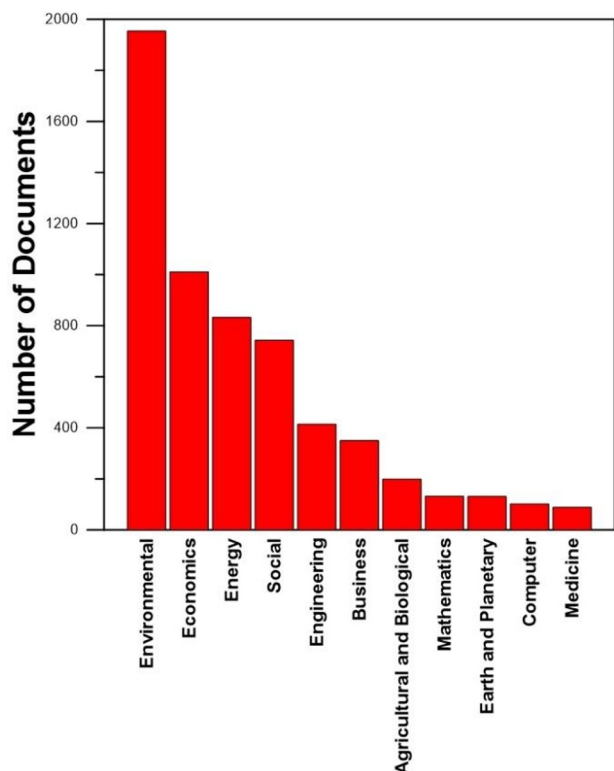

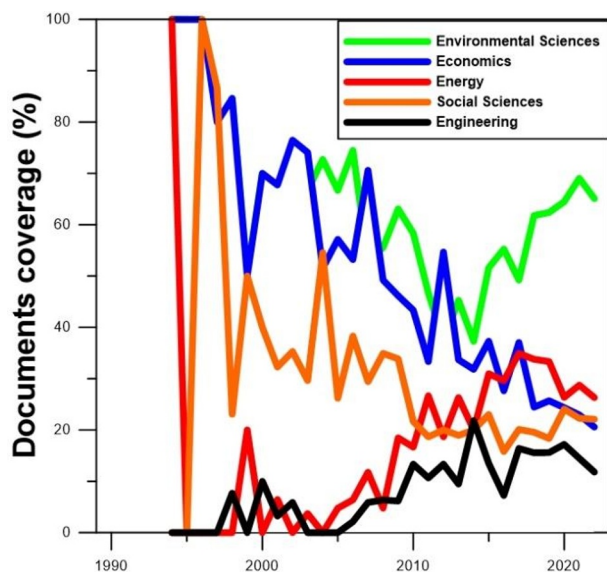**Fig. 8.** Total number of documents per scientific field.

Fig. 9. Evolution of the relative percentage of EKC documents per scientific field.

2.6 Keywords

The last criterion of the present analysis is focused on the keywords used and their frequency in the EKC documents. Scopus gives 159 keywords in total. The most

frequent on is "Kuznets Curve" (1,410 times). Except this keyword which is part of the search keywords, the other keywords in the top-5 keywords are: "Environmental Kuznets Curve", "Economic Growth", "Carbon Dioxide" and "Economic Development". The above keywords validate the previous scientific fields analysis, where environmental and economic issues are shown to be mostly examined.

To better analyse the scientific trends, the keywords are classed in nine main categories: Socio-economic variables (41 keywords with 6,791 total appearances), EKC (10 keywords with 4,198 total appearances), Polluting Elements (21 keywords with 3,907 total appearances), Environment (22 keyword with 3,770 total appearances), Methodology (23 keywords with 2,306 total appearances), Policy (19 keywords with 2,847 total appearances), Area/Countries (20 keywords with 1,760 total appearances), Energy (4 keywords with 407 total appearances) and Document's Type (3 keywords with 260 total appearances).

Even the most popular keywords (Kuznets Curve and Environmental Kuznets Curve) are involved in the second most famous category (EKC), socio-economic variables category shows the highest number of appearances, as it has been consisted of 40 keywords. Additionally, even if Methodology category includes the second most numbered 20 keywords, their appearance is less frequent, putting their total number in the fourth place of frequency. Energy and document's type categories are found in the last places of frequency as they involve much less keywords which are not often used in published documents.

Table 1. Keywords in main categories.

Keywords category	Total frequency
Socio-Economic variables	**6791**
Economic Growth	1080
Economic Development	753
Economics	671
Gross Domestic Product	295
Economic Growths	288
Renewable Energy	283
Energy Consumption	280
Energy Use	277
Urbanization	228
Income	226
Investments	171
Foreign Direct Investment	143
Financial Development	141
Trade Openness	130
Human	117
Globalization	97
Commerce	96
International Trade	94
Agriculture	94
Investment	92
Renewable Energy Consumption	88

Innovation	87
Humans	79
Trade	73
Trade-environmental Relations	70
Gross National Product	64
Industrial Economics	63
Industrialization	62
Per Capita	61
Income Distribution	61
Foreing Direct Investments	58
FDI	58
Energy Intensity	58
Tourism	57
Finance	56
Gross Domestic Products	54
Growth	53
Fuel Consumption	46
GDP	44
Population Density	43

Keywords category	Total frequency
EKC	**4198**
Kuznets Curve	1410
Environmental Kuznets Curve	1263
Environmental Kuznets Curves	661
EKC	267
Environmental Kuznets Curve Hypothesis	183
Environmental Kuznet's Curve	145
EKC Hypothesis	141
Environmental Kuznets Curve (EKC)	128
GDP	44
Population Density	43

Keywords category	Total frequency
Polluting Elements	**3907**
Carbon Dioxide	1053
Carbon Emission	724
CO2 Emissions 2	344
Carbon	214
Carbon Emissions	203
Carbon Dioxide Emissions	198
CO2 Emissions	139
Greenhouse Gases	121
Greenhouse Gas	98
Carbon Footprint	90
Fossil Fuels	88
Gas Emissions	84
Sulfur Dioxide	77
CO Emission 2	70
Industrial Emissions	67
Fossil Fuel	67
CO 2 Emission	67

Air Pollutants	55
Air Pollutant	51
Particulate Matter	49
Emission	48

Keywords category	Total frequency
Environment	**3770**
Environmental Economics	723
Pollution	404
Environmental Quality	351
Environmental Degradation	320
Environmental Pollution	200
Climate Change	192
Global Warming	189
Ecological Footprint	180
Environmental Impact	162
Environment	142
Air Pollution	142
Atmospheric Pollution	119
Environmental Pollutions	84
Pollution Haven Hypothesis	78
Ecology	77
Environmental Management	75
Deforestation	65
Air Quality	62
Environmental Technology	56
Water Pollution	54
Natural Resources	50
Natural Resource	45

Keywords category	Total frequency
Methodology	**2306**
Panel Data	296
Economic Analysis	292
Regression Analysis	193
Empirical Analysis	172
Hypothesis Testing	124
Cointegration Analysis	116
Spatiotemporal Analysis	96
Granger Causlity Test	96
Econometrics	93
Population Statistics	92
Cointegration	89
ARDL	68
Numerical Model	66
Error Correction	65
Time Series Analysis	59
Heterogeneity	52
Auto-regressive	52
Estimation Method	50
Analysis	50
Spatial Analysis	49
Granger Causality	46
Cross-sectional Study	46
Cross-sectional Studies	44

Keywords category	Total frequency
Policy	**2847**

Sustainable Development	425
Energy Utilization	341
Economic And Social Effects	283
Environmental Protection	214
Sustainability	210
Emission Control	194
Environmental Policy	180
Public Policy	168
Enegy Efficiency	110
Pollution Control	103
Environmental Sustainability	100
Energy Policy	109
International Cooperation	83
Internationality	69
Policy Making	64
Environmental Monitoring	53
Industry	49
Policy	47
Environmental Regulations	45

Keywords category	Total frequency
Area/Countries	**1760**
China	464
Developing Countries	127
India	123
Developing World	119
United States	83
Turkey	75
OECD	70
Europe	69
Asia	65
Africa	62
Eurasia	58
South Africa	56
European Union	56
Brazil	56
Pakistan	54
City	46
Malaysia	45
Developing Country	45
Russian Federation	44
Cities	43

Keywords category	Total frequency
Energy	**407**
Alternative Energy	179
Renewable Energies	99
Energy	82
Energy Resource	47

Keywords category	Total frequency
Document's Type	**260**
Article	207
Priority Journal	53

3 Conclusions

Environmental Kuznets Curve is a relatively new scientific field. However, despite being new, the annual production of documents is shows a continuously increasing trend. China, USA, Turkey and Pakistan are the countries with the highest production of documents. The main scientific fields are environmental science, economics and energy. The analysis of keywords used form the authors shows the main trends of this scientific field.

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