EWE

Environment and Water Engineering

Homepage: www.jewe.ir

ISSN: 2476-3683

Economic complexity and environmental performance: A global systematic review emphasizing institutional quality

Maryam Abedi[1], Amir Hossein Montazer Hojat[1]✉, Yaghoub Andayesh[1], and Behrooz Shahmoradi[4]

[1]Department of Economics, Faculty of Economics and Social Science, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[2]Department of Science, Technology and Innovation Financing and Economics, National Research Institute for Science Policy (NRISP), Tehran, Iran

ARTICLE INFO

Paper Type: Research Paper

Received: 21 May 2025
Revised: 25 July 2025
Accepted: 07 August 2025
Published: 07 August 2025

Keywords
Carbon Emission
Economic Complexity
Ecological Footprint
Institutional Quality
Sustainability

Corresponding author:
A. H. Montazer Hojat
✉ a.hojat@scu.ac.ir

ABSTRACT

This systematic review examines the relationship between economic complexity (ECI), institutional quality (IQ), and environmental performance (EP). This review bridges the critical gap in understanding how IQ mediates ECI's environmental impacts. For this purpose, we analyze 76 studies of environmental economics from 2017 to 2024, including ECI, which is increasingly used in the literature. The research is organized to respond to three main questions of research evolution, the literature focus, and implications. The results show that ECI significantly influences ecological footprints and carbon emissions, with effects varying by country development and institutional strength. ECI can reduce the EF in countries with robust institutions and higher levels of development. Our review reveals the Environmental Kuznets Curve (EKC) as the dominant framework in the literature. Key policy implications include strengthening institutions, promoting renewable energy, and tailoring strategies to country-specific contexts. Regarding the Sustainable Development Goals, this study highlights the essential role of the interplay of economic complexity, institutions, and environmental outcomes.

Highlights

- Analyzes ECI's link to environmental performance and other factors.
- Traces environmental economics research on ECI from 2017 to 2024.
- Synthesizes key themes and policy implications for sustainability.

Citing:

Abedi, M., Montazer Hojatt, A. H., Andayesh, Y., & Shahmoradi, B. (2025). Economic complexity and environmental performance: A global systematic review emphasizing institutional quality. *Environment and Water Engineering*, *11*(3), 387-402. https://doi.org/10.22034/ewe.2025.525883.2023

1. Introduction

Environmental degradation and climate change are among the biggest challenges threatening economic growth and sustainability. Based on the World Meteorological Organization (2023) the decade of 2011-2020 was the warmest on record, the ozone hole was smaller than the two previous decades, global mean sea level rose, and glaciers thinned by one meter per year on average. These environmental changes affect human life in various ways, from threatening food security to undermining long-term development efforts. In addition, climate change disrupts national economies and affects lives and livelihoods (The United Nations, 2024). In response, the UN has proposed several strategies aligned with its 17 Sustainable Development Goals. These involve investing in advanced technologies, renewable energy resources, promoting energy efficiency, and adopting clean energy technologies and infrastructure. From an economic perspective, knowledge and technological advancement are increasingly recognized as essential tools in addressing environmental challenges. Neoclassical economists suggest that by replacing natural resources with man-made capital, sustained growth is possible, especially if technological progress is rapid enough (Vatn, 2007). Essentially, they consider technological advancements and knowledge as key solutions to resource depletion and environmental harm. This viewpoint causes a global will towards a knowledge-based economic structure, which is visible in increased research focusing on the role of knowledge in environmental conservation efforts. Defining a suitable measure to capture the amount of knowledge in economic development has been a popular research topic. In recent years, researchers have developed various indices to measure the role of knowledge in economic development (Li et al, 2023). One of the most comprehensive indicators is the Economic Complexity Index (ECI), which has gained attention in environmental research, Can and Gozgor (2017); Boleti et al. (2021). ECI is known as a useful indicator of economic development and representation of skill, knowledge-based, and advanced production, which was not previously shown (Hausmann et al., 2014). Despite this growing interest, the literature still lacks a systematic review of how ECI relates to EP, institutional quality (IQ), and economic growth. This study aims to bridge the gap by reviewing 76 research papers published between 2017 and 2024. It explores the evolution of environmental research on ECI, identifies the main themes, and discusses the implications for sustainable development. Therefore, it answers three specific questions:

Q1: How has the environmental economics research on ECI evolved?

Q2: What is the focus of this literature?

Q3: What are the policy implications for sustainable development?

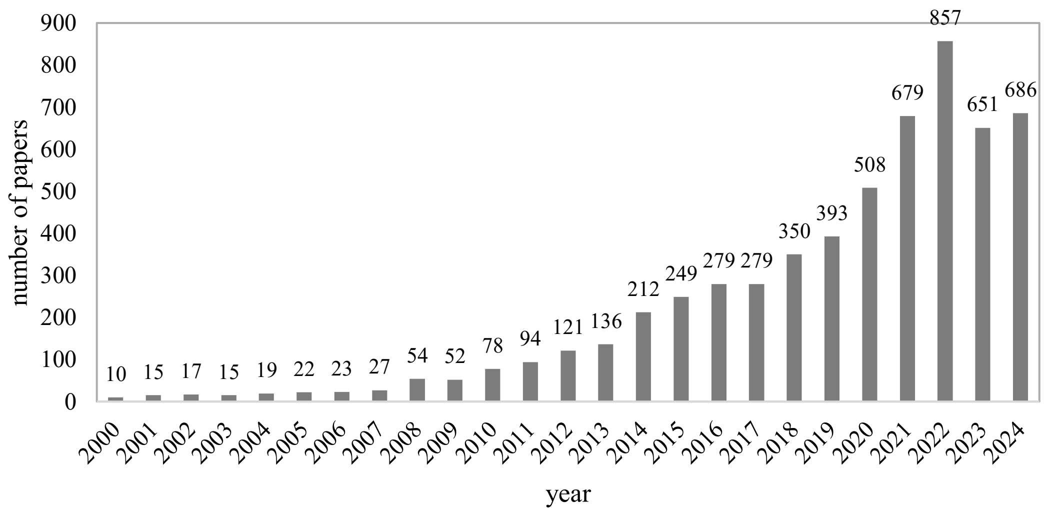
2. Methodology

This study includes a review of 76 research papers published from 2017 to the middle of 2024 that simulate the relationships between environmental indicators, ECI, and IQ indicators in various countries using different econometric models. To address the research questions, the following steps were undertaken (Webster & Watson, 2002).

2.1 Literature search strategy

Articles exploring the relationship between ECI, IQ, and environmental indicators are gathered from reputable scientific databases, including Google Scholar, ScienceDirect, and PubMed. The keywords used for the search include "economic complexity index," "environment," "institutional quality," and "ecological footprint." The search focuses on articles published between 2017 and 2024 (the articles are collected until August 2024; any papers published after this date are not included).

Fig. 1 Annual distribution of scientific articles on environmental issues and ECI, Source: PubMed



2.2 Eligibility criteria

The selection of articles is based on the following criteria:

- Articles must focus on environmental economics.
- Articles should examine the relationship between environmental indicators and one or both ECI and IQ.
- Articles must employ valid and diverse econometric methods.
- The relationship can be one-way or causal.

After applying these criteria, a total of 76 articles were selected for analysis.

2.3 Data extractions

After collecting the articles, we conducted a content analysis and extracted key information from every paper. The information was organized based on the publication year, geographical scope, dependent and independent variables, the theoretical framework, methods and statistical analyses, and the results.

2.4 Classification of findings

The findings are categorized according to three main research questions:

- Evolution of Research: Historical trends and changes in approaches to ECI within the literature of environmental economics.
- Focus of the Literature: Identification of key topics and research areas that have garnered the most attention.
- Implications: Examination of the overall results of the research for future policymaking and planning in the context of sustainable development.

In addition, given the significant differences in how ECI affects the environment based on countries and institutional conditions, the review examines IQ and geographical contexts separately, such as developed countries, developing countries, and G-7 nations.

2.5 Analysis of findings

We organized the findings in both quantitative and qualitative levels. In the quantitative section, the frequency distribution of the articles was classified and presented based on the key information extracted from each article. Following this, a qualitative analysis of the findings was conducted to address each of the research questions.

3. Quantitative findings

The number of scientific publications exploring the relationship between ECI and environmental indicators has significantly increased, as observed in the reviewed databases. For instance, Fig. 1 shows the number of scientific articles published in the PubMed database from 2000 to 2024 (The selection of articles for this research was conducted in August 2024, while Fig. 1 was updated from the PubMed database in December). Notably, the highest number of articles was published in 2022 (857 articles), followed by 2024 (686 articles). This indicates a growing focus on issues related to ECI and the environment.

After applying the selection criteria, a total of 76 articles were selected that analyze the impact of ECI, IQ, or both on various environmental aspects. The qualitative information related to these articles will be presented in a categorized format below.

3.1 Frequency distribution

As shown in Fig. 2, the highest number of articles was published in 2022. The first paper appeared in 2017, and there has been a gradual increase in the number of scientific publications up to 2022. However, the number of published articles has declined since then. As it is previously noted, the articles from 2024 are incomplete and cover only the first half of the year, which may contribute to the lower count. Table 1 shows the frequency distribution of the studies' geographical scope at international and national levels. Most articles (59) are at the international level, while 18 countries are analyzed at the national level, including China (3 articles), India (2 articles), Brazil and Pakistan (2 articles each), and other countries of Ghana, the United Arab Emirates, France, Indonesia, Japan, Bangladesh, Spain, Iran, the USA, and Chile (1 article each). The OECD and European countries are covered 12 times. The G7, G10, and G20 countries are explored in five articles, countries with the highest levels of ECI in four articles, and various groups of developed and developing countries in the remaining. These results show that the geographical scope is unbalanced, with limited representation from Latin American and Australian countries, especially at the national level.

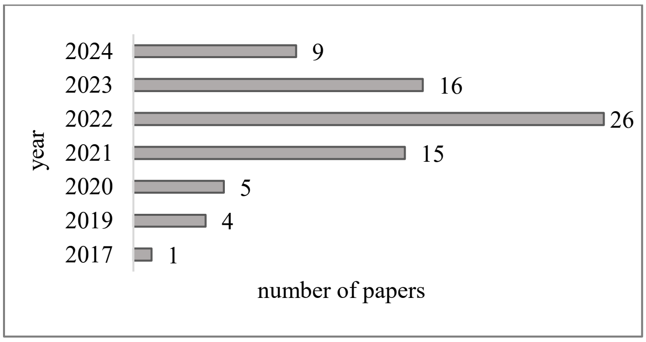


Fig. 2 Distribution of article frequency by year of publication

Table 1 The frequency distribution of the studies' geographical scope

Level	Details	Frequency
International	A world sample	16
	OECD countries	7
	European	5
	G-7, G-10, G-20 countries	5
	African	4
	emerging	4
	top complex countries	4
	E-7	3
	Asian	3
	BRICS	3
	PIIGS, former socialist transition, top exporting, Lancang-Mekong Cooperation, MENA	5
	Summation	59
National	India, Ghana, the United Arab Emirates, France, Indonesia, China, Brazil, Pakistan, Japan, Bangladesh, Spain, Iran, the USA, Chile	18

3.2 Dependent and independent metrics

A descriptive analysis of target metrics, including variables, indices, and indicators, used in the studies reveals that the ecological footprint (EF) is the most frequently cited, appearing in 32 articles, followed by carbon dioxide (CO_2) emissions in 31 articles. 22 studies employed various other metrics, such as Environmental Innovation Performance (EIP), Renewable Energy Production (REN) or consumption (REC), and the Green Job Index. However, these metrics are not reported separately due to their limited frequency. Fig. 3 illustrates the percentage frequency of the dependent metrics. Despite the advantages of the Ecological Footprint (EF), several common data-related issues affect the reliability and comparability of findings across studies. While EF is a comprehensive indicator, except Lee et al. (2022), who considers all six sub-kinds of EF, studies rely on the aggregate EF or EF per capita, rather than analyzing its six components (built-up land, carbon footprint, cropland, grazing land, fishing grounds, and forest area). These sub-components have different drivers and environmental implications. Focusing solely on the total EF may obscure important differences and lead to biased conclusions. Therefore, analyzing EF in its aggregated form is often considered inappropriate (Lee et al., 2022).

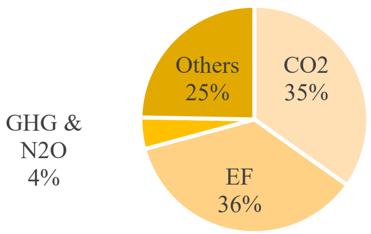


Fig. 3 The pie chart of the dependent metrics

The reviewed articles employ a total of 349 explanatory variables. As shown in Table 2, the most commonly used variables include ECI, all measures of economic growth, IQ, renewable energy, trade openness, and energy consumption (each used more than 20 times). Table 2 also presents other indicators that appear more than four times across the literature. The number of 22 additional variables was used fewer than four times and are therefore not listed individually. Although the widespread use of ECI warrants critical attention, Vu (2022) notes, ECI does not capture the sophistication of service products or account for non-exported goods, potentially underestimating the productive capacity of service-oriented or informal economies like Australia. This limitation raises concerns about the accuracy of ECI in cross-country comparisons.

3.3 Theoretical framework of the studies

This section reviews the various theoretical approaches employed in studies examining the relationships between environmental metrics and other economic and institutional variables and indicators. These approaches are generally categorized into three groups as follows.

3.3.1 Environmental Kuznets Curve

This approach is the most widely used theoretical framework for assessing the relationship between ECI and environmental indicators, as referenced in 34 studies. The Environmental Kuznets Curve (EKC) hypothesis posits an inverted U-shaped relationship between environmental degradation and economic growth, indicating that as countries grow economically, pollution initially increases but decreases after reaching a turning point. In the early stages of growth, poverty reduction takes precedence, often resulting in the neglect of environmental preservation and management; during this phase, nations typically prioritize the agenda: "Create wealth and clean up afterward."

Table 2 Frequency distribution of explanatory variables

Variable	Frequency
ECI	59
GDP, economic growth, income	57
IQ, democracy, bureaucracy, corruption control, governance	24
Renewable Energy	23
Trade Openness	22
Energy Consumption (EC) in general, and energy intensity	22
Urbanization (URB)	19
Population (POP) in general	16
Foreign Direct Investment (FDI)	13
Technological Innovation	11
Non-renewable / Fossil Fuel Energy Consumption	11
Globalization	10
Industry/ Industrialization	10
Natural Resources	9
Human Capital, Education	6
Financial Development	6
Agriculture	5
Capital Formation	4
Other variables < 4	22
Summation	349

However, in later stages of growth, significant increases in income levels, combined with effective IQ, awareness of environmental sustainability, and growth in technology and innovation, contribute to a reduction in environmental degradation. Studies suggest that ECI can influence this relationship, where higher ECI correlates with lower carbon emissions in advanced economies (Sarkodie & Strezov, 2019). Despite EKC's popularity, this framework oversimplifies by assuming environmental degradation is reversible or non-accumulative, which is problematic for issues like CO_2 emissions or biodiversity loss (Nguyen & Doytch, 2022).

Empirical evidence for the EKC is mixed and often inconsistent, varying significantly by pollutant, country, or time period (Kılıç et al., 2023), with some studies validating it for specific groups like the world's top 7 most complex economies (Martins et al., 2021) or G-7 countries (Balsalobre-Lorente et al., 2024), while others find it invalid or different shapes for nations like China (Yilanci & Pata, 2020). A major limitation in heterogeneous panel data studies is the lack of a well-defined common starting point for countries, which can lead to statistical issues where findings might extrapolate missing parts of a country's curve from data of differently developed nations (Bucher et al., 2023). Furthermore, the EKC may be influenced by the "pollution export hypothesis," where developed nations improve their environmental quality by offshoring "dirty industries" to developing countries (Nguyen & Doytch, 2022). Finally, the impact of economic complexity on environmental quality can vary across different income groups or be moderated by other factors like human development or innovation (Balsalobre-Lorente et al., 2024).

3.3.2 Causality

A total of 35 studies has evaluated the causal relationship between ECI and environmental indicators. The analysis of causality reveals that this relationship is often bidirectional, indicating that both factors can influence each other. The Dumitrescu-Hurlin test is the most frequently used causality test in these studies. Providing the mentioned insights into relationships, these models face significant challenges, especially in heterogeneous country samples. A critical limitation is the failure of many traditional "first-generation" econometric techniques to account for cross-sectional dependence (CD) and slope heterogeneity in panel data, which can lead to biased, inconsistent, and unreliable results, necessitating the use of more advanced "second-generation" methods like CS-ARDL, AMG, or Cup-FMOLS. Furthermore, these models often contend with endogeneity issues and reverse causality, where variables are jointly determined, making it difficult to isolate true causal effects, and can suffer from omitted variables bias if relevant factors are excluded (Hassan et al., 2023). The impact of variables can also vary heterogeneously across different quantiles or thresholds of environmental degradation or economic development (Lee et al., 2022). Finally, effects may be asymmetric: different impacts from positive vs. negative shocks, which traditional linear models may oversimplify (Khaliq & Mamkhezri, 2023).

3.3.3 The stochastic impacts by regression on population, affluence, and technology (STIRPA)

This approach assesses the relationships among population, wealth, and technology in relation to ECI and environmental indicators. Introduced by Dietz and Rosa (1997), this model is a refined version of the Impact = Population, Affluence, and Technology (IPAT) model by Ehrlich and Holdren (1972). A total of 10 studies has employed this approach. While STIRPAT is more adaptable than IPAT, allowing for the inclusion of other influential factors beyond the core three, and incorporating economic complexity as a representation of technology or structural change (Ahmed et al., 2022), it still has limitations. A primary oversimplification stems from its broad definition of "Technology," which can encompass various indicators like patents, renewable energy consumption, or economic complexity (Raza et al., 2023), leading to diverse model specifications and potentially inconsistent findings across studies (Nguyen & Doytch, 2022). Moreover, the STIRPAT model does not inherently account for nonlinear effects of significant environmental factors, and studies relying on it might oversimplify by assuming linear relationships if threshold effects are not explicitly modeled (Wang et al., 2023). As other methods have been used in a limited number of articles (three papers), they will not be addressed here due to their lack of widespread application. Fig. 4 illustrates the frequency distribution of approaches.

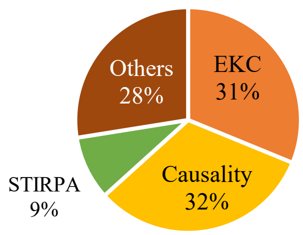


Fig. 4 The Pie Chart of Theoretical Frameworks

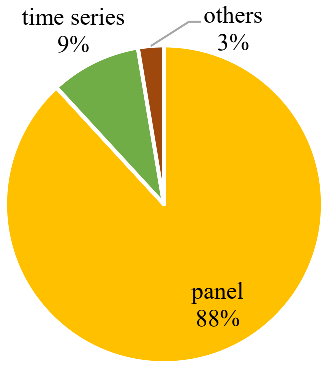
3.4 Modeling and methods

Two main approaches have been used in the literature to statistically infer relationships between variables. The first is modeling approaches, which estimate the impact of explanatory variables on the target variable. The second is causal approaches, which examine causal relationships between variables. Below, a quantitative analysis of the diversity and number of tests categorized by these two approaches is provided. It is important to note that because panel data structures have been used most frequently in articles, modeling methods tailored for this data structure are the most employed. Fig. 5 shows the percentage frequency of various data structures in the studies.

3.4.1 Modeling approaches

A total of 39 methods have been used for estimation in the articles, as shown in Fig. 6, which lists the names and frequency distribution of each method. As indicated in Fig. 6, Autoregressive Distributed Lag (ARDL)-based methods are the most popular, including Panel Autoregressive Distributed Lag (PARDL), Cross-Sectional Autoregressive Distributed Lag (CS-ARDL), Quantile Autoregressive Distributed Lag (QARDL), Fourier ARDL (F-ARDL), and Augmented Autoregressive Distributed Lag (AARDL), with a total of 29 studies employing these methods. Following ARDL, Dynamic Ordinary Least Squares (DOLS) has been used in 10 studies, while Fully Modified Ordinary Least Squares (FMOLS), Augmented Mean Group (AMG), and System-Generalized Method of Moment (Sys-GMM) rank next with frequencies of 9, 7, and 7, respectively. For the frequency of other methods, please refer to Fig. 6.

Fig. 5 The Pie Chart of data structures



3.4.2 Causality tests

Studies indicate that ECI can play a dual role in EF. Causality analyses allow for the identification of dynamic and directional relationships between variables.

A total of 34 papers applied causality tests alongside associative analyses. The methods used in the articles to test causality between variables can be categorized into three main groups. The most popular method is the Dumitrescu and Hurlin causality test. This approach, which applies in 20 studies, is based on the Granger causality test and is particularly for a panel data structure. The second popular method is Granger causality. It is a classical method that examines simpler causal relationships between variables and is used in 3 papers.

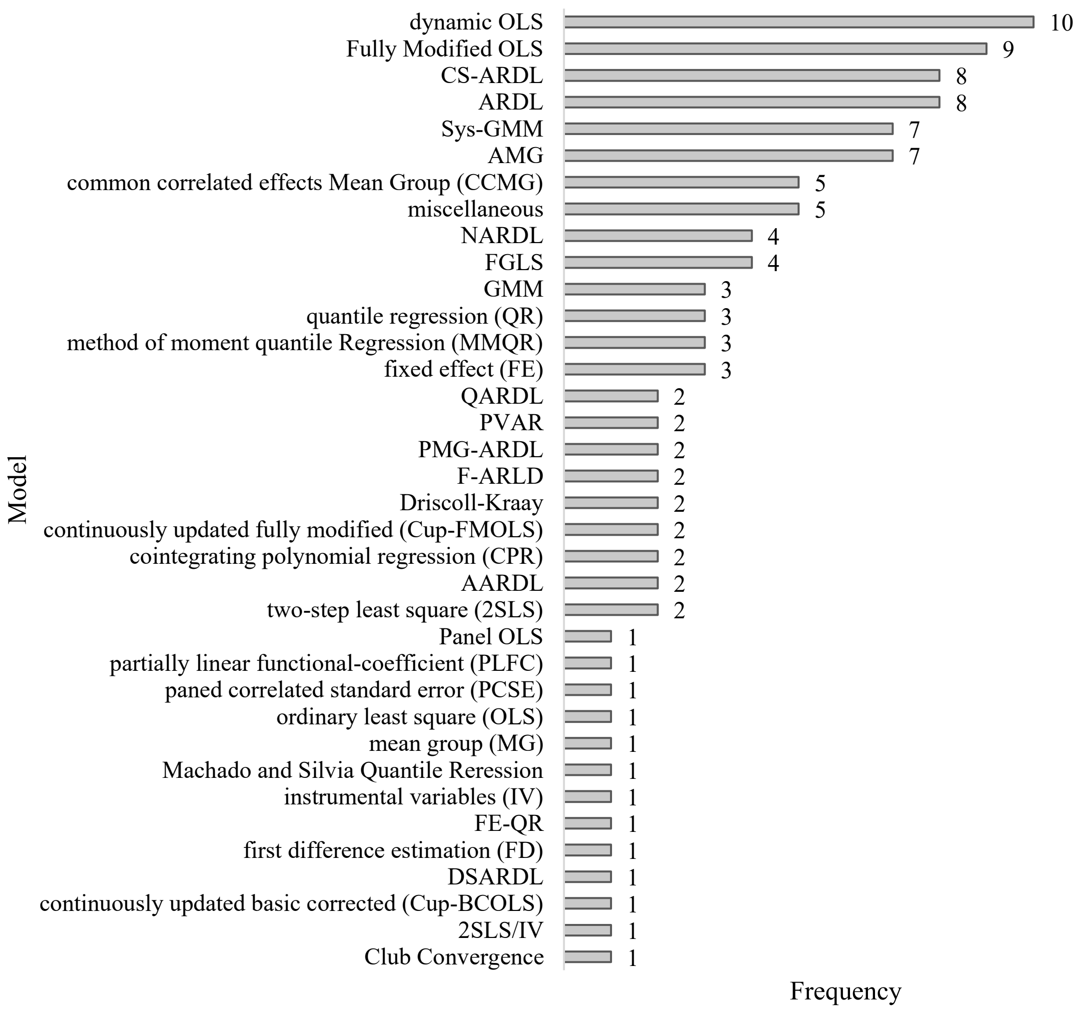


Fig. 6 The frequency distribution of modeling approaches

There are many other methods, which have been used sporadically, that are presented in Table 3. In summary, recent research shows growing interest in the ECI-environment link, with diverse methods and data used. Subsequently, targeted qualitative analyses are performed to address the research questions.

Table 3 The frequency distribution of causality test

causality test	frequency
Dumitrescu–Hurlin	20
Granger causality	3
Quantile Granger Causality	2
Emirmahmutoglu and Kose Granger causality	2
asymmetric Granger causality	1
bootstrap Toda–Yamamoto modified Wald (MWALD)	1
Granger non-causality	1
Hacker and Hatemi bootstrap causality	1
Juodis et al. (2021) novel panel Granger	1
Konya bootstrap panel causality	1
The vector error correction model (VECM)	1
Toda and Yamamoto	1
Grand Total	34

4. Evolution of research

As global environmental issues increase, researchers are focusing more on studying the relationship between knowledge-based economic growth and environmental outcomes such as CO2 emissions and EF. Studies indicate that over the last five years, particularly in 2022 and 2024, the number of publications in this area has grown significantly. This shows the importance of the topic in scientific research.

The trend analysis shows that the EKC hypothesis is a widely used framework in early research, which paved the way for the ECI entrance into environmental studies. Since its introduction in 2017, the ECI has been increasingly utilized in selected research. Can and Gozgor (2017) were the first to use the ECI as a measure of knowledge-based, skill-based, and complex production within the EKC model. Their study on France demonstrates that the ECI reflects a country's ability to produce complex goods. They suggest that countries with higher ECI are able to reduce carbon emissions more effectively. These results drove researchers to investigate the ECI's role in reducing the environmental impacts of economic growth. By 2019, four different studies had been conducted internationally and within the European Union. They incorporate the ECI as a variable in the EKC model. The findings are not homogeneous. For instance, Azizi et al. (2019) concluded that a long-term increase in ECI leads to carbon emissions in countries. In contrast, Arnaut & Dada (2022) found that developed countries benefit environmentally from ECI, yet it worsens carbon emissions in developing nations. Boleti et al. (2021) noted that while higher ECI improves the Environmental Performance Index (EPI), it also increases carbon emissions. Neagu (2019) discovered that the relationship between ECI and carbon emissions in selected EU countries follows an inverted-U pattern in the EKC, which means that as production becomes more complex, carbon emissions increase earlier, but after a certain threshold, ECI contributes to a reduction in carbon emissions. These different results of studies cause ambiguities around the impact of the ECI on environmental variables.

Since ECI measures the diversity and complexity of a country's production and economic structures, it can show the knowledge-based economic growth. The reviewed papers continued to more explicitly examine the role of the ECI. Gradually, ECI has emerged as a critical indicator in understanding the relationship between economic activities and EF. Neagu (2020) was the first paper that used EF in their study. They showed that an increase in ECI can lead to a reduction in the EF. These results align with Shahmoradi and Ellili (2024), who found that higher economic complexity is associated with a lower ecological footprint. Following this, the EF was used as a target variable in 27 other studies, either alone or alongside CO_2. However, results continued to vary. Some studies, such as Numan et al. (2022) and Abou Houran and Mehmood (2023), showed that greater complexity leads to more environmental degradation, while others, including Shahzad et al. (2021) and Ahmed et al. (2022), found the opposite results. This encouraged studies to identify control variables that influence the positive or negative relationship between the ECI and CO2 or the EF. Abdi (2023) found that while ECI can improve environmental quality in the long term, it can also lead to challenges in carbon emissions. If a country's ECI relies on the use of renewable energy, it can enhance environmental quality; otherwise, it can degrade the environment in areas where industrialization and urbanization are not properly managed. Emmanuel et al. (2023) , showed that the differences in results stem from different levels of development among countries. In developed countries, due to greater innovation, ECI improves environmental quality, whereas in developing countries, rapid industrialization can have a negative effect. Sabir et al. (2020) identified differences in energy efficiency, reliance on fossil fuels, and governance structures as important factors in this context.

4.1 ECI–EP Determinants

The determinants of the positive or negative relationship between the ECI and environmental performance can be categorized into the following sections.

4.1.1 Time Period

Some studies indicate that although higher ECI can result in environmental degradation in the short term, it may have the opposite effect in the long term. This conclusion is drawn by Abdi (2023)in his analyses of Sub-Saharan African countries. He highlights the importance of transitioning towards knowledge-based production activities and utilizing renewable energy, and he also suggests that ECI can accelerate structural changes that provide environmental outcomes.

4.1.2 IQ as a Mediating Variable

The role of IQ has been explored in nine studies such asAbou Houran and Mehmood (2023) , Boleti et al. (2021), and Bucher et al. (2023). The findings emphasize that strong institutions can reduce the negative impacts of ECI on the environment (Section 5.2 provides a comprehensive discussion around IQ).

4.1.3 Energy Consumption

47 studies have highlighted the importance of consuming renewable energy to reduce EF and CO2 emissions. Reliance on non-renewable energy sources leads to environmental harm, while investing in renewable energy can lower pollution

levels. Thus, countries must change their energy consumption combination toward clean and renewable sources as they develop (Wang et al., 2023).

4.1.4 GDP Per Capita

The income level of a country is the potential to either reduce or increase the environmental quality. On one hand, higher income levels can result in more negative environmental effects, because countries may put greater pressure on natural resources to increase consumption and production. On the other hand, high-income countries are more capable of implementing effective environmental policies and using cleaner technologies. Although this variable has not resolved the ongoing ambiguity, it was a progress that led to incorporating sustainability into the literature.

4.1.5 Geographical Scope

Khaliq and Mamkhezri (2023) , Lee et al. (2022), and Yilanci and Pata (2020) are of papers that explored the role of geographical differences. The results show that in G-7 or developed countries, ECI tends to have positive effects on the environment because of their advanced technologies and more complex economic systems. In contrast, countries with weaker or developing economies encounter challenges, such as higher energy consumption and increased pollution, as they pursue economic growth.

4.1.6 Globalization

Globalization is considered in ten articles as an explanatory variable. The results show that each economic, social, or political globalization has different effects on the environment. According to Dada et al. (2023) , ECI and political globalization reduce environmental footprints, but overall globalization, especially at social and economic levels, degrades the environment. They argue that African countries have failed to sustainably take advantage of globalization. The lack of environmental policies prevents these countries of taking advantage of globalization, such as environmentally friendly technologies and research and development activities.

4.2 Methodological evolution

Modeling techniques in the literature have progressed in sophistication. Earlier studies, such as those by Can and Gozgor (2017), Azizi et al. (2019) , and Neagu and Teodoru (2019), utilized DOLS-based approaches. As panel data become more widely used, both cross-country interdependencies and differences are found. The differences stem from variations in economic structure, energy systems, and pollution emissions. However, countries in the same region (e.g. European Union (EU) countries) may have convergence due to their shared market and policies. Consequently, studies start to evaluate cross-sectional dependence, the presence of unit roots, and cointegration to analyze data stability and the long-term relationships among the variables. Following these initial tests, the Fully Modified Ordinary Least Squares (FMOLS) and Dynamic Ordinary Least Squares (DOLS) models were employed to estimate long-term elasticities between dependent and independent variables(Neagu & Teodoru, 2019). Other methods, such as panel quantile regression, the fixed-effects two-stage least squares/instrumental variables (FE 2SLS/IV) strategy, and System GMM, have also been used sporadically in earlier studies. After Sabir et al. (2020), Autoregressive Distributed Lag (ARDL) approaches gained popularity for analyzing both long-term and short-term relationships. More recent papers have used advanced techniques like Quantile Regression to examine effects across different segments of the data distribution (such as analyzing effects in high- and low-income countries). Despite these methodological advances, the literature still presents mixed results. This underlines the need for more research, especially cross-country comparisons and time-series studies, to better understand how institutional quality interacts with ECI. Clarifying these relationships could help policymakers make more informed decisions to reduce the negative impacts of ECI on the environment.

5. Focus of the research literature

To examine the focus area of the research literature, the VOS Viewer software is utilized. Fig. 7 depicts the timeline of keywords, where color indicates the topic and the size of the spheres represents their frequency. The connecting lines show how the keywords are related to one another. Initially, studies concentrated on uncertainty and complexity, but over time, as the topic of sustainable development emerged, issues such as climate change and sustainability began to receive more attention. The ECI's larger yellow sphere shows its significant role. This index is associated with EF, carbon emissions, renewable energy, and IQ. It is evident that newer studies not only make greater use of these indicators but also aim to understand the relationships among them to resolve previously mentioned ambiguities. The connections between ECI and EF and IQ will be explored in greater detail in the following sections.

5.1 ECI and environmental indicators

The literature centers on understanding the interrelationship between ECI and environmental indicators, and answers the question of whether ECI enhances environmental quality or contributes to its degradation. For this reason, the Environmental Kuznets Curve (EKC) hypothesis has been examined in 43% of studies to investigate the nonlinear relationship between ECI and environmental indicators.

Carbon emissions and greenhouse gases were initially the most frequently used environmental indicators in studies. However, as time passed, papers have shown a growing preference for various EF indicators of production, consumption, and carbon. The EF indicates how much biologically productive land and water is needed by an individual, population, or activity, both to produce the resources consumed and to absorb the waste generated, based on common technologies and resource management practices (Global Footprint Network, 2023).One advantage of this indicator is its ability to assess the biocapacity of various land uses. The EF and biocapacity are calculated across six categories of land use: Cropland, grazing land, fishing ground, forest land, built-up land, and carbon uptake land. Notably, earlier studies primarily employed aggregate indicators like total EF, but over time, researchers have increasingly shifted towards using more specific indicators, such as the carbon EF.

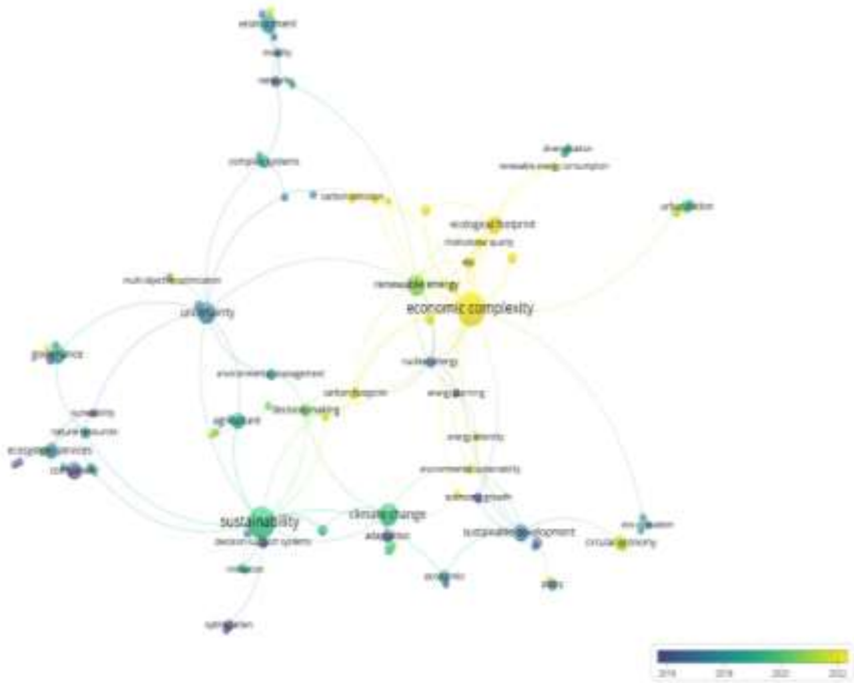


Fig. 7 keywords of the literature regarding the importance and time

Another area of focus in the research literature is identifying the variables and indicators that mediate the relationship between ECI and environmental quality metrics. These variables include the type of energy consumed, IQ, and globalization(Ahmad et al., 2021), green innovations(Adebayo, Altuntaş, et al., 2022), financial development (Arnaut & Dada, 2022), human capital (Amegavi et al., 2022), and urbanization (Abdi, 2023).

5.2 The contribution of institutional quality

From a technological perspective, the economic structure is influenced by various factors such as institutions, education, and management, which are reflected in the diversity of produced technologies within an economy (Shahmoradi et al., 2021). As mentioned in Section 4.1.2, the research literature focuses particularly on IQ, its various dimensions, and their environmental impacts. IQ indicates the effectiveness of governance and the performance of a country (Rafei et al., 2022), and is measured across dimensions such as control of corruption, government effectiveness, political stability and absence of violence/terrorism, regulatory quality, rule of law, and voice and accountability (World Bank, 2023).

A group of studies has identified IQ as a mediating variable in the relationship between ECI and EF. Ahmad et al. (2021) suggest that higher IQ alleviates the negative effects of ECI on the EF, thus it benefits the environment. Raza et al. (2023) demonstrate that a greater IQ can reduce EF. Some studies have also explored the interactions between IQ and other factors. For example, Udemba (2021) assessed the interactions between IQ and foreign direct investment (FDI) in relation to environmental performance, Agu et al. (2025) investigates how economic governance institutions are moderating the effect of economic complexity on trade, FDI inflow, environmental degradation, and economic growth, and Sajid et al. (2024) concluded that IQ strengthens the relationship between ECI and CO_2 emission.

Another group of studies has investigated the direct relationship between IQ and environmental quality. They indicate that improved IQ can result in EF reduction and less environmental degradation (Ahmad et al., 2021). Emmanuel et al. (2023) stated that IQ consistently enhances environmental quality. Uzar (2021) shows that IQ reduces EF in E-7 countries. On the other hand, Hussain and Dogan (2021) emphasize that in BRICS countries, IQ has a negative effect on EF.

The IQ indices are typically published by the Worldwide Governance Indicators (WGI), the International Country Risk Guide (ICRG), and the Economic Freedom of the World (EFW). All of them report some sub-dimensions for IQ that may have different environmental impacts. While the studies have made valuable contributions by examining the role of IQ in the literature, most have relied on composite indices of IQ. A few exceptions exist, such as Wang and Yang (2022) showed that components such as bureaucracy quality, government stability, law and order, and investment profile can enable green complexity to reduce CO_2 emissions. This means that the improving effect of complexity depends on the quality of specific institutional features. Similarly, Amegavi et al. (2022) focused on bureaucratic quality, and Sabir et al. (2020) assessed the rule of law and government stability. Therefore, institutional sub-components influence the effectiveness of economic complexity in promoting environmental sustainability. Apart from these three studies, disaggregated approaches remain rare in the literature. Research mostly continues to consider IQ a unified index, while this approach overlooks how different parts of governance affect the ECI-EF relationship. In addition to the gap in studies that analyze all three indices (ECI, EF, and IQ), there is another less-studied gap to examine how each dimension of IQ may influence this relationship. Bridging both gaps could help create better and more specific policy recommendations for sustainable development.

The Paris Agreement COP21 highlights the importance of sustainable and green economic growth in reducing environmental degradation and facilitating structural changes for lower carbon consumption. Countries are transitioning from economies reliant on agriculture and energy-intensive production to complex, knowledge-based economies. The ECI captures the diversity of industrial systems and productive structures within countries, enabling the prediction and explanation of differences in economic growth and carbon emissions among them (Hidalgo, 2021). Additionally, institutions directly and indirectly impact climate change; for example, higher IQ can reduce environmental harm and lower the costs of economic growth (Ahmad et al., 2021) . North (1990) posits that institutions are human-made rules that arise from a society's thought processes. While institutions can influence the behaviors and choices of individuals and communities, those individuals and communities shape the institutions. Understanding how institutions affect society is as crucial as recognizing that they are products of human creation (Vatn, 2007). This suggests a potential bidirectional relationship between the quality of institutions in a society and the metrics that measure community growth and development. Furthermore, Halicioglu (2009) indicates that, on one hand, higher economic growth demands more energy and resources, which are major contributors to environmental degradation. On the other hand, changing energy and resource consumption patterns requires a high level of economic development. Thus, the causal relationship between environmental variables and economic growth may be bidirectional. Despite the theoretical literature stressing the interconnections among EF, ECI, and IQ, few studies assess all three indices simultaneously. As Table 4 indicates, only three studies, marked in green, have tackled this important topic. In Ahmad et al. (2021) , IQ mediates ECI-EF. Abou Houran and Mehmood (2023) explored the impacts of ECI and IQ on EF, yet no clear conclusions show the role of IQ; it was noted that its effect on EF remains ambiguous and uncertain. In Dada et al. (2023), only corruption is addressed. Overall, a significant gap in the research literature is the analysis of the interrelationships among EF, ECI, and IQ.

Table 4 The summary of studies categorized by the metrics used

Reference	EF	IQ	ECI	Place and Period
Can and Gozgor (2017)			1	France 1964-2014
Azizi et al. (2019)			1	99 countries 1992-2017
Aluko et al. (2023)	1		1	35 OECD 1998-2017
Boleti et al. (2021)		1	1	88 countries 2002, 2012
Neagu (2019)			1	25 selected EU countries 1995-2017
Neagu and Teodoru (2019)			1	25 EU countries 1995-2016
Chu (2020)		1	1	118 countries 2002-2014
Neagu (2020)	1		1	8 complex economies 1995-2014
Sabir et al. (2020)	1	1		South Asian countries 1984-2019
Swart and Brinkmann (2020)			1	The regions of Brazil
Yilanci and Pata (2020)	1		1	China 1965–2016
Agozie et al. (2022)			1	Brazil, Russia, India, China, South Africa 1990-2019
Adedoyin et al. (2021)			1	Global 1995-2016
Ahmad et al. (2021)	1	1	1	20 emerging countries
Boleti et al. (2021)		1	1	88 countries 2002-2012
Balsalobre-Lorente et al. (2024)	1		1	G-7 1991-2018
Doğan et al. (2021)			1	28 OECD countries 1990-2014
Dordmond et al. (2021)			1	27 Brazilian states 2003-2013
Hussain and Dogan (2021)	1	1		BRICS economies 1992-2016
Ikram et al. (2021)	1		1	Japan 1965Q1 to 2017Q4
Liu et al. (2021)			1	LM Cooperation countries 1991 to 2017
Martins et al. (2021)			1	Top 7 economic complex countries 1993-2018
Moridian et al. (2021)	1		1	Iran 1965-2017
Agu et al. (2025)		1	1	Africa 2000-2020
Al-Ayouty (2024)			1	MENA 1990-2020
Romero and Gramkow (2021)			1	7 countries 1976-2012
Shahzad et al. (2021)	1		1	The USA 1965Q1 to 2017Q4
Udemba (2021)		1		Chile 1996Q1 to 2018Q4
Uzar (2021)	1	1		E-7 countries 992–2015
Adebayo, Altuntaş, et al. (2022)			1	Top economic complex countries 1993-2018
Alsabhan and Tahir (2024)			1	BRICS 1998-2022
Ahmed et al. (2022)	1		1	India 1970-2017
Amegavi et al. (2022)	1	1		Ghana 1984-2016
Arnaut and Dada (2022)	1		1	the United Arab Emirates 1995-2017 Quarter
Chandrarin et al. (2022)			1	Indonesia 1966 to 2018
Demiral and Akça (2022)			1	22 EU countries 1995-2018
Hussain and Mahmood (2022)	1	1		Pakistan 1984-2019

Reference	EF	IQ	ECI	Place and Period
Aydin et al. (2024)		1	1	China 1995-2022
Kazemzadeh et al. (2022)	1		1	98 countries 1990 - 2014
Bakhsh et al. (2024)			1	OECD 1995-2022
Lee et al. (2022)	1		1	99 countries 2006 - 2017
Liu et al. (2022)			1	selected 15 Asian nations 1990 2019
Majeed et al. (2022)			1	OECD countries 1971 -2018
Marco et al. (2022)			1	Spain 2002-2016
Balsalobre-Lorente et al. (2022)			1	PIIGS 1990-2019
Caglar et al. (2022)			1	BRIC 1990-2018
Doğan et al. (2022)		1	1	G-7 & E-7 1991-2017
Neagu and Neagu (2022)	1		1	the first 48 complex economies 1995-2017
Nguyen and Doytch (2022)	1		1	95 economies 1995-2013
Numan et al. (2022)	1		1	85 countries 2001-2020
Radmehr et al. (2022)	1			G7 countries 1990-2018
Esmaeili et al. (2023)			1	N-11 1995-2019
Vu (2022)		1	1	115 countries average of 2000-2010
Wan et al. (2022)	1		1	India 1990-2018
Wang and Yang (2022)		1		78 countries 1995-2014
You et al. (2022)			1	95 countries 1996–2015
Abdi (2023)			1	41 sub-Sahran African countries 1999-2018
Abou Houran and Mehmood (2023)	1	1	1	Next 11 nations1995-2018
Bucher et al. (2023)		1	1	27 former socialist countries1995-2017
Ha (2023)		1	1	24 European countries 2011-2019
Khezri et al. (2022)			1	29 Asia-Pacific countries 2000-2018
Dada et al. (2023)	1	1	1	24 African countries 2000-2017
Emmanuel et al. (2023)	1	1		101 countries 1995-2017
Ha (2023)		1	1	24 European countries 2011-2019
Ha (2023)	1		1	OECD countries 1990-2019
Kazemzadeh et al. (2023)			1	The G7 countries 1990–2019
Khaliq and Mamkhezri (2023)			1	Bangladesh, India, Pakistan, Sri Lanka 1995 – 2019
Kibria (2023)	1		1	Bangladesh 1995 - 2018
Kılıç et al. (2023)	1		1	10 countries1970 - 2017
Raza et al. (2023)	1	1		G20 countries 1990-2021
Sajid et al. (2024)		1	1	Chian & Pakistan 1996-2021
Uche et al. (2022)	1		1	E-7 1990-2018
Wang et al. (2023)	1		1	36 OECD countries 1998-2018
Balsalobre-Lorente et al. (2024)	1		1	G-7 countries 1991-2018
Ntang et al. (2024)	1		1	20 African countries 1991-2014
Ünsal (2024)			1	35 OECD countries 2002-2021

6. Policy implications

Based on the concepts discussed in the previous sections, some policy implications are recommended in this section. First, a strong institutional framework is essential for effective environmental governance and maximizing the benefits of environmental policies (Emmanuel et al., 2023). Therefore, governments should enhance the rule of law, ensure governance stability, combat corruption, and improve bureaucratic efficiency. Due to the limited research on the individual dimensions of institutional quality, it remains unclear which dimension should be prioritized in policy. Nevertheless, we suggest that countries with weak institutional quality must improve all aspects, and they can begin with the ones that are easiest to address regarding their specific circumstances. Given the complex relationship between ECI and its environmental impacts, as the second implication, development policies should aim to minimize environmental harm. Environmental protection measures not only directly reduce degradation but also lower the risk of pollution havens. Besides, policies such as carbon taxes and emission reduction should align with enhancements in IQ and its dimensions. Moreover, policies should promote the transition to cleaner energy consumption patterns. Measures such as providing subsidies, investing in infrastructure development, and implementing supportive regulations encourage the adoption and expansion of renewable energy sources while reducing fossil fuel dependency. Investment in research and development (R&D) to support green innovation and the use of environmentally friendly technologies is also recommended. Encouraging economic diversification toward more complex and knowledge-based industries, particularly green sectors, contributes to more sustainable economic growth.

We also suggest that globalization management should be aimed at maximizing environmental benefits and minimizing potential harms. According to Dada et al. (2023) Political globalization positively influences environmental quality, so it should be a strategic priority for developing countries. Simply put, policymaking should consider the specific context and development stage of different countries, as well as the relationship between ECI, growth, and the environment. Finally, this review offers insights for sustainable development as follows:

- Strengthen Institutions. Most studies have used composite measures of institutional quality, while recent findings show that specific parts of institutions, such as bureaucratic quality, government stability, and investment profile, can affect the relationship between ECI and EF in different ways. Therefore, we suggest that governments to focus on both the unified IQ index and its sub-dimensions.

- Promote Renewable Energy to decouple economic complexity from environmental degradation.

- Tailor Policies to Context. Developed nations should leverage advanced technologies, while developing countries need capacity-building for sustainable industrialization.

- Invest in Green Innovation: Support R&D in green technologies to foster sustainable growth.

These recommendations align with SDGs 7 (Affordable and Clean Energy), 9 (Industry, Innovation, and Infrastructure), and 16 (Peace, Justice, and Strong Institutions), providing actionable pathways for global sustainability.

7. Conclusion

This study reviewed 76 papers on the relationship between ECI, Environmental Performance, and IQ. The main findings are as follows:

1. The impact of ECI on the environment depends on factors such as the level of development, quality of institutions, and use of renewable energy. In countries with strong institutions and advanced technologies, higher ECI is often linked to better environmental outcomes.

2. In developing countries with weak institutions, ECI may not improve environmental performance and can sometimes worsen it. Per capita income shows mixed effects: in some contexts, it supports environmental quality, while in others it leads to more degradation.

3. Employing advanced econometric models shows that complex, multifactorial analyses and causality assessments are essential for a clear understanding of the relationships between ECI and environmental indicators.

The main limitations and suggestions for future research are as follows:

- Geographical coverage: Many regions, especially Africa, Latin America, and Australia, are less considered. Future studies should focus more on these areas.

- Disaggregated indicators: More attention is needed to the sub-components of EF and IQ. Analyzing their separate effects can provide deeper insights.

- Meta-analysis: Applying meta-analytic tools like meta-regression could improve the reliability of results and help identify stronger patterns across studies.

Statements and Declarations

Data availability

The datasets generated and analysed during the current study are available from the corresponding author upon request.

Conflicts of interest

The author of this paper declared no conflict of interest regarding the authorship or publication of this paper.

Author contribution

M. Abedi: formal analysis, investigation, data curation, writing original draft; A. H. Montazer Hojat: project administration, writing - review & editing; Y. Andayesh: writing – review & editing; and B. Shahmoradi: conceptualization.

AI Use Declaration

During the preparation of this manuscript, the authors used the free versions of ChatGPT and Sider for translation purposes from Persian to English. However, the authors affirm that they reviewed, edited, and approved the final text.

References

Abdi, A. H. (2023). Toward a sustainable development in sub-Saharan Africa: do economic complexity and renewable energy improve environmental quality? *Environmental Science and Pollution Research*, *30*(19), 55782-55798. https://doi.org/10.1007/s11356-023-26364-z

Abou Houran, M., & Mehmood, U. (2023). How institutional quality and renewable energy interact with ecological footprints: do the human capital and economic complexity matter in the Next Eleven nations? *Environmental Science and Pollution Research*, 1-13. https://doi.org/10.1007/s11356-023-26744-5

Adebayo, T. S., Altuntaş, M., Goyibnazarov, S., Agyekum, E. B., Zawbaa, H. M., & Kamel, S. (2022). Dynamic effect of disintegrated energy consumption and economic complexity on environmental degradation in top economic complexity economies. *Energy Reports*, *8*, 12832-12842. https://doi.org/10.1016/j.egyr.2022.09.161

Adedoyin, F. F., Nwulu, N., & Bekun, F. V. (2021). Environmental degradation, energy consumption and sustainable development: accounting for the role of economic complexities with evidence from World Bank income clusters. *Business Strategy and the Environment*, *30*(5), 2727-2740. https://doi.org/10.1002/bse.2774

Agozie, D. Q., Akwasi Gyamfi, B., Victor Bekun, F., Ozturk, I., & Taha, A. (2022). Environmental Kuznets Curve hypothesis from lens of economic complexity index for BRICS: Evidence from second generation panel analysis. *Sustainable Energy Technologies and Assessments*, *53*, 102597. https://doi.org/10.1016/j.seta.2022.102597

Agu, C., Ogbuabor, J. E., & Onah, B. U. (2025). How are Economic Governance Institutions Moderating the Effect of Economic Complexity on Trade, FDI Inflow, Environmental Degradation, and Economic Growth in Africa? *Journal of the Knowledge Economy*, *16*(2), 9536-9567. https://doi.org/10.1007/s13132-024-02284-2

Ahmad, M., Ahmed, Z., Majeed, A., & Huang, B. (2021). An environmental impact assessment of economic complexity and energy consumption: does institutional quality make a difference? *Environmental Impact Assessment Review*, *89*, 106603. https://doi.org/10.1016/j.eiar.2021.106603

Ahmed, Z., Can, M., Sinha, A., Ahmad, M., Alvarado, R., & Rjoub, H. (2022). Investigating the role of economic complexity in sustainable development and environmental sustainability. *International Journal of Sustainable Development & World Ecology*, *29*(8), 771-783. https://doi.org/10.1080/13504509.2022.2097330

Al-Ayouty, I. (2024). Economic Complexity and Renewable Energy Effects on Carbon Dioxide Emissions: a Panel Data Analysis of Middle East and North Africa Countries. *Journal of the Knowledge Economy*, *15*(3), 12006-12025. https://doi.org/10.1007/s13132-023-01540-1

Alsabhan, T. H., & Tahir, M. (2024). The moderating role of income on the complexity–sustainability nexus: evidence from BRICS members. *Sustainability*, *16*(23), 10171. https://doi.org/10.3390/su162310171

Aluko, O. A., Opoku, E. E. O., & Acheampong, A. O. (2023). Economic complexity and environmental degradation: Evidence from OECD countries. *Business Strategy and the Environment*, *32*(6), 2767-2788. https://doi.org/doi.org/10.1002/bse.3269

Amegavi, G. B., Langnel, Z., Ahenkan, A., & Buabeng, T. (2022). The dynamic relationship between economic globalisation, institutional quality, and ecological footprint: Evidence from Ghana. *The Journal of International Trade & Economic Development*, *31*(6), 876-893. https://doi.org/10.1080/09638199.2022.2033303

Arnaut, M., & Dada, J. T. (2022). Exploring the nexus between economic complexity, energy consumption and ecological footprint: new insights from the United Arab Emirates. *International Journal of Energy Sector Management*, *17*(6), 1137-1160. https://doi.org/10.1108/IJESM-06-2022-0015

Aydin, M., Guney, E., Yigit, B., Acikgoz, F., & Cakmak, B. Y. (2024). Regulatory pathways to green energy transition for sustainable environment: The fostering role of human rights, banking sector development, economic complexity, and economic freedom. *Journal of Environmental Management*, *366*, 121739. https://doi.org/10.1016/j.jenvman.2024.121739

Azizi, Z., Daraei, F., & Boroujeni, A. N. (2019). The impact of economic complexity on environmental pollution. *Economic Development Policy*, *7*(2), 201-219. https://doi.org/10.22051/EDP.2020.29451.1225

Bakhsh, S., Zhang, W., Ali, K., & Anas, M. (2024). Energy transition and environmental stability prospects for OECD economies: The prominence role of environmental governance, and economic complexity: Does the geopolitical risk matter? *Journal of Environmental Management*, *354*, 120358. https://doi.org/10.1016/j.jenvman.2024.120358

Balsalobre-Lorente, D., Ibáñez-Luzón, L., Usman, M., & Shahbaz, M. (2022). The environmental Kuznets curve, based on the economic complexity, and the pollution haven hypothesis in PIIGS countries. *Renewable Energy*, *185*, 1441-1455. https://doi.org/10.1016/j.renene.2021.10.059

Balsalobre-Lorente, D., Nur, T., Topaloglu, E. E., & Evcimen, C. (2024). Assessing the impact of the economic complexity on the ecological footprint in G7 countries: Fresh evidence under human development and energy innovation processes. *Gondwana Research*, *127*, 226-245. https://doi.org/10.1016/j.gr.2023.03.017

Boleti, E., Garas, A., Kyriakou, A., & Lapatinas, A. (2021). Economic complexity and environmental performance: evidence from a world sample. *Environmental Modeling & Assessment*, *26*(3), 251-270. https://doi.org/10.1007/S10666-021-09750-0

Bucher, F., Scheu, L., & Schröpf, B. (2023). Economic complexity and environmental pollution: Evidence from the former socialist transition countries. *Empirica*, *50*(3), 807-847. https://doi.org/10.1007/s10663-023-09575-y

Caglar, A. E., Zafar, M. W., Bekun, F. V., & Mert, M. (2022). Determinants of CO_2 emissions in the BRICS economies: The role of partnerships investment in energy and economic complexity. *Sustainable Energy Technologies and Assessments*, *51*, 101907. https://doi.org/10.1016/j.seta.2021.101907

Can, M., & Gozgor, G. (2017). The impact of economic complexity on carbon emissions: evidence from France. *Environmental Science and Pollution Research*, *24*(19), 16364-16370. https://doi.org/10.1007/s11356-017-9219-7

Chandrarin, G., Sohag, K., Cahyaningsih, D. S., & Yuniawan, D. (2022). Will economic sophistication contribute to Indonesia's emission target? A decomposed analysis. *Technological Forecasting and Social Change*, *181*. 121758. https://doi.org/10.1016/j.techfore.2022.121758

Chu, L. K. (2020). Economic structure and environmental Kuznets curve hypothesis: new evidence from economic complexity. *Applied Economics Letters*, *28*(7), 612-616. https://doi.org/10.1080/13504851.2020.1767280

Dada, J. T., Ajide, F. M., & Al-Faryan, M. A. S. (2023). Economic complexity and ecological degradation in Africa: does globalization matter? *The International Trade Journal*, 1-29. https://doi.org/10.1080/08853908.2023.2243328

Demiral, M., & Akça, E. E. (2022). Economic complexity–carbonization nexus in the European Union: A heterogeneous panel data analysis. *Energy Sources, Part B: Economics, Planning, and Policy*, *17*(1), 2046210. https://doi.org/10.1080/15567249.2022.2046210

Dietz, T., & Rosa, E. A. (1997). Effects of population and affluence on CO_2 emissions. *Proceedings of the national academy of sciences*, *94*(1), 175-179.

Doğan, B., Driha, O. M., Balsalobre Lorente, D., & Shahzad, U. (2021). The mitigating effects of economic complexity and renewable energy on carbon emissions in developed countries. *Sustainable Development*, *29*(1), 1-12. https://doi.org/10.1002/sd.2125

Doğan, B., Ghosh, S., Hoang, D. P., & Chu, L. K. (2022). Are economic complexity and eco-innovation mutually exclusive to control energy demand and environmental quality in E7 and G7 countries? *Technology in Society*, *68*, 101867. https://doi.org/10.1016/j.techsoc.2022.101867

Dordmond, G., de Oliveira, H. C., Silva, I. R., & Swart, J. (2021). The complexity of green job creation: An analysis of green job development in Brazil. *Environment, Development and Sustainability*, *23*, 723-746. https://doi.org/10.1007/s10668-020-00605-4

Ehrlich, P. R., & Holdren, J. P. (1972). One-dimensional economy. *Bull At Sci*, *28*(5), 16-27.

Emmanuel, O. N. B., Fonchamnyo, D. C., Thierry, M. A., & Dinga, G. D. (2023). Ecological footprint in a global perspective: the role of domestic investment, FDI, democracy and institutional quality. *Journal of Global Responsibility*. https://doi.org/10.1108/JGR-09-2022-0091

Esmaeili, P., Lorente, D. B., & Anwar, A. (2023). Revisiting the environmental Kuznetz curve and pollution haven hypothesis in N-11 economies: Fresh evidence from panel quantile regression. *Environmental Research*, *228*, 115844. https://doi.org/10.1016/j.envres.2023.115844

Global Footprint Network, D. (2023). *National Footprint and Biocapacity Accounts* https://data.footprintnetwork.org/#/abouttheData

Ha, L. T. (2023). Is economic complexity an enabler of environmental innovation? Novel insightful lessons from European region. *Management of Environmental Quality: An International Journal*, *34*(2), 331-350. https://doi.org/10.1108/MEQ-08-2022-0244

Ha, L. T. (2023). Is economic complexity an enabler of environmental innovation? Novel insightful lessons from European region. *Management of Environmental Quality: An International Journal*, *34*(2), 331-350. https://doi.org/10.1108/MEQ-08-2022-0244

Halicioglu, F. (2009). An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy*, *37*(3), 1156-1164.

Hassan, S. T., Batool, B., Wang, P., Zhu, B., & Sadiq, M. (2023). Impact of economic complexity index, globalization, and nuclear energy consumption on ecological footprint: First insights in OECD context. *Energy*, *263*, 125628. https://doi.org/10.1016/j.energy.2022.125628

Hausmann, R., Hidalgo, C. A., Bustos, S., Coscia, M., & Simoes, A. (2014). *The atlas of economic complexity: Mapping paths to prosperity*. Mit Press.

Hidalgo, C. A. (2021). Economic complexity theory and applications. *Nature Reviews Physics*, *3*(2), 92-113.

Hussain, M., & Dogan, E. (2021). The role of institutional quality and environment-related technologies in environmental degradation for BRICS. *Journal of Cleaner Production*, *304*, 127059. https://doi.org/10.1016/j.jclepro.2021.127059

Hussain, M., & Mahmood, N. (2022). Do positive and negative shocks of institutional quality affect the ecological footprint in a developing economy? *Social Responsibility Journal*. https://doi.org/10.1108/SRJ-02-2022-0100

Ikram, M., Xia, W., Fareed, Z., Shahzad, U., & Rafique, M. Z. (2021). Exploring the nexus between economic complexity, economic growth and ecological footprint: contextual evidences from Japan. *Sustainable Energy Technologies and Assessments*, *47*, 101460. https://doi.org/10.1016/j.seta.2021.101460

Kazemzadeh, E., Fuinhas, J. A., Koengkan, M., & Osmani, F. (2022). The Heterogeneous Effect of Economic Complexity and Export Quality on the Ecological Footprint: A Two-Step Club Convergence and Panel Quantile Regression Approach. *Sustainability*, *14*(18), 11153. https://doi.org/10.3390/su141811153

Kazemzadeh, E., Fuinhas, J. A., Radulescu, M., Koengkan, M., & Silva, N. (2023). The heterogeneous impact of the environmental policy stringency on premature indoor and outdoor deaths from air pollution in the G7 countries: do economic complexity and green innovation matter? *Atmospheric Pollution Research*, *14*(2), 101664. https://doi.org/10.1016/j.apr.2023.101664

Khaliq, A., & Mamkhezri, J. (2023). Asymmetrical analysis of economic complexity and economic freedom on environment in South Asia: A NARDL approach. *Environmental Science and Pollution Research*, *30*(38), 89049-89070. https://doi.org/10.1007/s11356-023-28481-1

Khezri, M., Heshmati, A., & Khodaei, M. (2022). Environmental implications of economic complexity and its role in determining how renewable energies affect CO2 emissions. *Applied Energy*, *306*, 117948. https://doi.org/10.1016/j.apenergy.2021.117948

Kibria, M. G. (2023). Ecological footprint in Bangladesh: Identifying the intensity of economic complexity and natural resources. *Heliyon*, *9*(4). https://doi.org/10.1016/j.heliyon.2023.e14747

Kılıç, C., Soyyiğit, S., & Bayrakdar, S. (2023). Economic Complexity, Ecological Footprint, and the Environmental Kuznets Curve: Findings from Selected Industrialized Countries. *Journal of the Knowledge Economy*, 1-26. https://doi.org/10.1007/s13132-023-01411-9

Lee, C.-C., Chen, M.-P., & Wu, W. (2022). The criticality of tourism development, economic complexity, and country security on ecological footprint. *Environmental Science and Pollution Research*, *29*(24), 37004-37040. https://doi.org/10.1007/s11356-022-18499-2

Liu, H., Alharthi, M., Zafar, M. W., Tahir, M. S., & Asghar, M. M. (2022). Understanding the role of technology in Asian economies: the environmental impact of remittances and economic complexity. *Evaluation Review*, 0193841X221120483. https://doi.org/10.1177/0193841X221120483

Liu, H., Liang, S., & Cui, Q. (2021). The nexus between economic complexity and energy consumption under the context of sustainable environment: Evidence from the LMC countries. *International Journal of Environmental Research and Public Health*, *18*(1), 124. https://doi.org/10.3390/ijerph18010124

Majeed, M. T., Mazhar, M., Samreen, I., & Tauqir, A. (2022). Economic complexities and environmental degradation: evidence from OECD countries. *Environment, Development and Sustainability*, *24*(4), 5846-5866. https://doi.org/10.1007/s10668-021-01687-4

Marco, R., Llano, C., & Pérez-Balsalobre, S. (2022). Economic complexity, environmental quality and income equality: A new trilemma for regions? *Applied Geography*, *139*, 102646. https://doi.org/10.1016/j.apgeog.2022.102646

Martins, J. M., Adebayo, T. S., Mata, M. N., Oladipupo, S. D., Adeshola, I., Ahmed, Z., & Correia, A. B. (2021). Modeling the relationship between economic complexity and environmental degradation: evidence from top seven economic complexity countries. *Frontiers in Environmental Science*, 398. https://doi.org/10.3389/fenvs.2021.744781/full

Moridian, A., Yarmohammadian, N., Motalebi, M., & Shadmehr, A. (2021). The Role of Economic Complexity in the Ecological Footprint: A Review of the EKC Hypothesis for Iran. *Planning and Budgeting*, *26*(2), 153-179. https://doi.org/10.52547/jpbud.26.2.153

Neagu, O. (2019). The link between economic complexity and carbon emissions in the European Union countries: a model based on the Environmental Kuznets Curve (EKC) approach. *Sustainability*, *11*(17), 4753. https://doi.org/10.3390/su11174753

Neagu, O. (2020). Economic Complexity and Ecological Footprint: Evidence from the Most Complex Economies in the World. *Sustainability*, *12*(21), 9031. https://doi.org/10.3390/su12219031

Neagu, O., & Neagu, M.-I. (2022). The Environmental Kuznets Curve revisited: economic complexity and ecological footprint in the most complex economies of the world. *Studia Universitatis Vasile Goldiş Arad, Seria Ştiinţe Economice*, *32*(1), 78-99. https://sciendo.com/2/v2/download/article/10.2478/sues-2022-0005.pdf

Neagu, O., & Teodoru, M. C. (2019). The relationship between economic complexity, energy consumption structure and greenhouse gas emission: Heterogeneous panel evidence from the EU countries. *Sustainability*, *11*(2), 497. https://doi.org/10.3390/su11020497

Nguyen, C. P., & Doytch, N. (2022). Does knowledge matter for the environment? Global evidence of economic complexity and ecological footprints. *Environmental Science and Pollution Research*, *29*(54), 82122-82139. https://doi.org/10.1007/s11356-022-21547-6

North, D. (1990). *Institutions, Institutional Change, and Economic Performance*. Cambridge University Press.

Ntang, P. B., Baida, L. A., & Abba Yadou, B. (2024). How does economic complexity influence environmental degradation? New insights from African countries. Natural resources forum,

Numan, U., Ma, B., Meo, M. S., & Bedru, H. D. (2022). Revisiting the N-shaped environmental Kuznets curve for economic complexity and ecological footprint. *Journal of Cleaner Production*, *365*, 132642. https://doi.org/10.1016/j.jclepro.2022.132642

Radmehr, R., Shayanmehr, S., Ali, E. B., Ofori, E. K., Jasińska, E., & Jasiński, M. (2022). Exploring the nexus of renewable energy, ecological footprint, and economic growth through globalization and human capital in g7 economics. *Sustainability*, *14*(19), 12227. https://doi.org/10.3390/su141912227

Rafei, M., Esmaeili, P., & Balsalobre-Lorente, D. (2022). A step towards environmental mitigation: How do economic complexity and natural resources matter? Focusing on different institutional quality level countries. *Resources Policy*, *78*, 102848.

Raza, A., Habib, Y., & Hashmi, S. H. (2023). Impact of technological innovation and renewable energy on ecological footprint in G20 countries: The moderating role of institutional quality. *Environmental Science and Pollution Research*, *30*(42), 95376-95393. https://doi.org/10.1007/s11356-023-29011-9

Romero, J. P., & Gramkow, C. (2021). Economic complexity and greenhouse gas emissions. *World Development*, *139*, 105317. https://doi.org/10.1016/j.worlddev.2020.105317

Sabir, S., Qayyum, U., & Majeed, T. (2020). FDI and environmental degradation: the role of political institutions in South Asian countries. *Environmental Science and Pollution Research*, *27*, 32544-32553. https://doi.org/10.1007/s11356-020-09464-y

Sajid, S., Abas, A., Hassan, S. S. U., & Arooj, M. (2024). The interaction of institutional quality, economic complexity, and carbon dioxide emission: An empirical examination for China and Pakistan. *Sustainable Futures*, *7*, 100222. https://doi.org/10.1016/j.sftr.2024.100222

Sarkodie, S. A., and Strezov, V. (2019). A review on environmental Kuznets curve hypothesis using bibliometric and meta-analysis. *Science of the total environment*, *649*, 128-145.

Shahmoradi, B., & Ellili, N. O. D. (2024). Bibliometric review of research on economic complexity: current trends, developments, and future research directions. *Journal of Industrial and Business Economics*, *51*(4), 859-891. https://doi.org/10.1007/s40812-024-00298-0

Shahmoradi, B., Chiniforooshan, P., & Sarkhosh Sara, A. (2021). Identification and ranking of technologies affecting inequality: A study of selected countries with emphasis on Iran. *Journal Strategic Studies of Public Policy*, *11*(40), 102-131.

Shahzad, U., Fareed, Z., Shahzad, F., & Shahzad, K. (2021). Investigating the nexus between economic complexity, energy consumption and ecological footprint for the United

States: New insights from quantile methods. *Journal of Cleaner Production*, *279*, 123806. https://doi.org/10.1016/j.jclepro.2020.123806

Swart, J., & Brinkmann, L. (2020). Economic complexity and the environment: evidence from Brazil. Universities and sustainable communities: meeting the goals of the agenda 2030,

The United Nations. (2024). *The Sustainable Development Agenda*. Retrieved 29 July from https://www.un.org/sustainabledevelopment/development-agenda/

Uche, E., Das, N., Nwaeze, N. C., and Bera, P. (2022). Navigating the paths to sustainable environments via energy security, renewable energy and economic complexity: Evidence from array of pollution metrics. *Energy & Environment*, *35*(3), 1434-1455. https://doi.org/10.1177/0958305X221140571

Udemba, E. N. (2021). Mitigating environmental degradation with institutional quality and foreign direct investment (FDI): new evidence from an asymmetric approach. *Environmental Science and Pollution Research*, *28*(32), 43669-43683. https://doi.org/10.1007/s11356-021-13805-w

Ünsal, Y. (2024). Economic complexity and environmental sustainability: sectoral perspectives from OECD countries. *Journal of Environmental Studies and Sciences*. https://doi.org/10.1007/s13412-024-00958-6

Uzar, U. (2021). The relationship between institutional quality and ecological footprint: Is there a connection? Natural Resources Forum,

Vatn, A. (2007). *Institutions and the Environment*. Edward Elgar Publishing.

Vu, T. V. (2022). Does institutional quality foster economic complexity? The fundamental drivers of productive capabilities. *Empirical Economics*, *63*(3), 1571-1604. https://doi.org/10.1007/s00181-021-02175-4

Wan, X., Jahanger, A., Usman, M., Radulescu, M., Balsalobre-Lorente, D., & Yu, Y. (2022). Exploring the effects of economic complexity and the transition to a clean energy pattern on ecological footprint from the Indian perspective. *Frontiers in Environmental Science*, *9*, 816519. https://doi.org/10.3389/fenvs.2021.816519

Wang, E.-Z., & Yang, M. (2022). Green complexity and CO_2 emission: Does institutional quality matter? *Energy Economics*, *110*, 106022. https://doi.org/10.1016/j.eneco.2022.106022

Wang, Q., Yang, T., & Li, R. (2023). Economic complexity and ecological footprint: the role of energy structure, industrial structure, and labor force. *Journal of Cleaner Production*, *412*, 137389. https://doi.org/10.1016/j.jclepro.2023.137389

Webster, J., & Watson, R. T. (2002). Analyzing the past to prepare for the future: Writing a literature review. *MIS quarterly*, xiii-xxiii.

World Bank, G. I. (2023). *World governance indicators* (https://databank.worldbank.org/databases/control-of-corruption

World Meteorological Organization. (2023). *The Global Climate 2011-2020: A decade of accelerating climate change* (WMO-No. 1338). WMO. https://library.wmo.int/records/item/68585-the-global-climate-2011-2020

Yilanci, V., & Pata, U. K. (2020). Investigating the EKC hypothesis for China: the role of economic complexity on ecological footprint. *Environmental Science and Pollution Research*, *27*(26), 32683-32694. https://doi.org/10.1007/s11356-020-09434-4

You, W., Zhang, Y., & Lee, C.-C. (2022). The dynamic impact of economic growth and economic complexity on CO_2 emissions: An advanced panel data estimation. *Economic Analysis and Policy*, *73*, 112-128. https://doi.org/10.1016/j.eap.2021.11.004