



Enhancing Environmental Quality in the Extended BRICS Countries through Economic Complexity, and Effective Governance

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ARTICLE INFO

Article History:

Received: October 20, 2025
Revised: November 18, 2025
Accepted: December 27, 2025
Available Online: December 15, 2025

Keywords:

Economic Complexity, Institutional Quality, Energy Consumption, Marginal Effect Model, EKC, BRICS

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ABSTRACT

From a broad perspective, the purpose of this research is to study the ecological outcomes of the complexity of the economy of the extended BRICS countries. In this respect, we are going to evaluate the outcomes of the empirical study in three different ways. Primary focus remained on the Driscoll-Kraay standard errors method to the data set of 1991 to 2023. We began by assessing the potential of complexity of the economy and the quality of institutions in affecting the environment and the direct relation to the quality of the environment. Further, we modified the Environmental Kuznets Curve (EKC) and for the purpose of this study we labeled it the Economic Complexity-based Environmental Kuznets Curve (ECX-EKC) and it deals with complexity of the economy and environmental impacts in the short and long run. This study in particular tries to study the marginal impacts on the quality of the environment as a result of the economic complexity and the quality of the institutions. The study outlines that in the given economies of the sample, environmental quality, economic growth, complexity of the economy, foreign direct investment, and the energy consumption, are all interconnected positively. This study is the first of its kind looking into the environmental impacts and degradation as a result of foreign direct investment, complexity of the economy, and economic growth in the countries of BRICS. The introduction of the ECX-EKC theory and the causation standing behind the paradox of complexity of economy to the sustainability were as a result of the quality of institutions and the legal arrangements that were present. Driscoll and Kraay standard errors method ascertains that the countries of BRICS depict an inverted U-shaped Environmental Kuznets Curve and more logical explanations are going to be introduced for the three different rationales to the EKC. This study demonstrated that an economy with strong institutional frameworks positively correlated with environmental outcomes of economic complexity over the long term.

Introduction

The last twenty years have seen, in large part, the world's energy framework affected and changed by newer and immediate challenges in the climate, the environment, and the geopolitics of energy (Feng, R. 2024). Climate change is now one of the most immediate and greatest challenges currently affecting all the nations of the world, and especially the extended BRICS (Brazil, Russia, India, China, South Africa, UAE, Iran, Egypt and Ethiopia) emerging market economies with China and India, the second and fifth greatest economies of the world, respectively (Yadav et al, 2024). Based on the Global Innovation Index 2023, China, Russia, and Brazil are all classified as economies in the upper middle-income range. Also, India, Brazil, and South Africa are leaders in Regional Innovation with China following (Global Innovation Index, 2023).

The intricate economies of the BRICS countries have generated unparalleled social prosperity and innovation due to their influence on the developing economies, which have created new policy demands on climate and inequality and health (Wang et al., 2023; Balland et al., 2022). These countries also have a high level of economic growth but suffer from poor environmental quality (Caglar et al., 2022). Economic complexity, according to W. Arthur in the 1980s, suggests that the world economy is in a state of disequilibrium and is always changing due to unpredictability and innovation (Arthur, 2013; Mercure, 2022). However, in the case of developing countries like the BRICS, it is not the case that economic growth will produce a better environment; this gap requires one to consider the extent to which these economies undergo technologically-advanced and knowledge-intensive change (Andrew et al., 2024).

Per data from the World Economic Forum and various international trade analyses, the economic complexity of the economy describes the sophistication of the economy and the range and depth of the economy's exports, specifically in the areas of knowledge generation, technology, and structural change within the economy (Dada et al, 2023). Economic complexity is ascertained through the evaluation of comparative advantage which determines the efficiency of a given economy in producing and exporting goods as well as considering the diversity and ubiquity of the export market which refers to the portfolio of various goods that the economy exports and the number of economies that export the same goods. A country is considered to have a developed and complex economy where there is a range of diversity in the country's exports and the volume of exports is high (Ajide, K. B. 2024).

The economic activities of a country are usually the prime contributors to the global environmental and climate change including the new challenges of global warming. These activities are complex and infringe on the myriad innovations that tech and also export diversification. These activities are also the ones that most researchers and policymakers aim to improve given their complexity in nature as they relate to the quality of the environment. Economic complexity of a country is also constructively related to the environmental quality as much as it does on the innovative measures or technology that is used in the production processes of the economy (Ahmad et al., 2021). The complexity of the economy defines the role that quality of the institutions have as they impose or enhance the rigid environmental improvement mechanisms on the economy which in turn facilitates rapid development of the economy (Amin et al, 2023).

With how important institutional quality is, this is the second study that looks into the possible connections economic complexity, energy consumption, and the technological innovation ecological footprint in the BRICS economies. As the world energy needs grow, the production and consumption of energy will be worthy of research, especially in the BRICS countries (Hasan, M. 2022). Economic complexity and the research ecosystem have had a contradictory relationship (Pata, U. K. 2021; Dada et al., 2023), and that has made the research about the BRICS economies

very scarce. This study will be the first of its kind to take a look in the BRICS economies to see how complexity of an economy affects the environmental conditions of a country.

This research aims at three things: the first is to find the correlation between the economic complexity with energy utilization, the quality of the institutions present, and the overall condition of the environment. The second is to analyze how the quality of institutions affect the environment as a result of the economic complexity present. The last is to test the theory of the economic complexity and environmental Curve (ECX-EKC) by adding the squared economic complexity term. The analysis in this paper will aid policymakers and state leaders in addressing the most significant environmental challenges.

The paper is divided into different parts. The second part is a review of the literature that exists with respect to the economic complexity and the quality of institutions. The third part is a description of the survey instruments and the ideas that were used to conduct the study. The fourth, fifth, and sixth parts present the data that were used to conduct the study, the analytical approach, and the main results and a description of the methods that were used to verify the results. The seventh part is the conclusion and gives the recommendations that can be drawn for policies, and the eighth part gives a description of the gaps that the study left and new studies that can be useful in this area in the future.

Literature review

Economic Complexity and Global Environmental Issues is motivated from examining the cope the impact of economic complexity and environmental consequences. Thus, empirical reaction can be classified in patterns of five major grouping. First, we consider and assess the evidence of the environmental consequences of economic complexity. First we discuss the economic literature around the institutional quality, and second we assess the literature on energy use, and third we discuss the interaction of economic complexity with institutional quality. Finally, we assess the economic complexity with the environmental based Kuznets curve.

Economic Complexity-Environment Nexus

Scholarly work regarding the implications of ECX (economic complexity) on the environment show that such work is still relevant. To illustrate, Andrew et al. (2024) state that more elaborate economies foster growth and innovation, for the advancement of technology, all the while stating that such growth may harm the environment on occasion, since the growth of the economy leads to increased emissions in the short run. However, with further complexity, economies may enhance the environmental and energy efficiency of the economy positively. This has also been acknowledged by exporters of more diversified and sophisticated products, Djeunankan et al. (2023) and Agozie et al. (2022) enhance EC (increase in energy efficiency). Ahmed et al. (2022) also made the same observation that the complexity of an economy is positively correlated with the reduction of ecological footprints. Therefore, increased economic complexity, with greater knowledge and innovation, can bring about more sustainable development. Finally, the complexity of Africa's economy is positively correlated with quality of institutions and financial development, as noted by Olaniyi and Odhiambo (2023) on the cognition that institutional quality can enhance the utilization of financial resources for more complex structures.

Adversely research indicating the other side of the spectrum (Adverse effect of economic complexity on sustainable development of the environment) is more cautionary. Sajid et al. (2024) found the economic complexity is a driver of emissions for Pakistan and China. However, the environmental ineptitude of the institutions of Pakistan is of poor quality resulting in, poor institutional quality, emissions Pakistan. While Dada et al. (2023) corrected the relation of

economic complexity, political globalization and ecologically responsive, focused more on globalization and the environment detriment of the African countries. Further, Ajide (2024) suggested a diminishing influence of foreign direct investment on the economic complexity, only in the case of improved trade suggesting a position of environmental degradation. This to find is not an indicator of the changing face of economic growth for environmental sustainable development, however, there will be a deteriorating imbalance complex institution frameworks, and stagnated over globalization construct complex economic frameworks to sustain environmental.

Institutional Quality-Environment Nexus

The positive impact of institutional quality and press freedom on environmental sustainability has been corroborated in various researches. For example, Riti et al. (2021) argues that, within the context of the Environmental Kuznets Curve (EKC) theory, in the context of press freedom, the inverse relationship of CO₂ emissions and economic growth can be seen. That is, in economically free countries that can be democratically governed, the initial positive relationship of economic growth and environmental degradation is reversed at later points of economic development. Likewise, Azizi and Daraei (2022) reports that enhanced governance and economic diversification in developing countries results in reduced inequalities in income and inequality, corroborating the perspective that strong institutions foster growth in developing countries. Also, Jhanger et al. (2022) in centers of the implications of political freedom to the positive impact of renewable energy on the reduction of environmental pressure. Also, Latif and Faridi (2023) shows that in Asian countries the existence of strong institutions enhance the positive impact that financial development has on sustainability while Rafei et al. (2022) depicts economic diversification and natural resource utilization as vital in shaping the of economic activities the sustainability of its resources. Khan et al. (2024) on the other hand, summarize the relationships of institutional quality, economic growth and CO₂ emissions to advocate for positive relationships to be encouraged in policy making, focusing on sustainable development and environmental conservation.

On the other hand, there are challenges and adverse effects of the relationship between institutional quality and economic growth. For example, Jhanger et al. (2022) stated that financial development harms the economy, and subsequently, he points out that globalization worsens the economy by harming the environment, thus implying that economic growth is not always beneficial for the environment. Khan et al. (2022) illustrates that even if there is potential for institutional quality to lessen the adverse impact of economic growth and energy usage i.e. CO₂ emissions, the lack of income and foreign direct investment, coupled with global economic growth and energy usage, can worsen the impact of CO₂ emissions. Hence, while there can be no doubt that strong institutions have a key role to play that is not the sole relationship between economic growth and the environment, there are key underpinning issues that require the attention of policymakers.

Energy-Environment Nexus

Databases that analyze the relationships between economic development, the use of renewable energy, and the reduction of carbon emissions showcase the work of several key researchers. From the work of Justice et al. (2024), we learn that renewable energy plays a key role in the direct mitigation of carbon emissions, while Yadav et al. (2024) made a positive correlation between economic growth and the use of renewable energy in the BRICS economies, leading to the conclusion that economically growing countries tend to use renewable energy to a greater extent. In a similar fashion, Abbas et al. (2024) showed that the use of renewable energy resources fosters economic growth and greater economic and product complexity, thus economically paving the way for the low carbon future. Finally, Sun et al. (2022) revealed that, in the case of economic

complexity, the use of renewables together with innovative technologies leads to a substantial reduction in carbon emissions, which justifies a positive correlation between strategic investment in renewable technologies and carbon emissions within the economy. Collectively, the database advocates for policies that remove barriers to the use of renewable energy and promote economic growth.

On the other side of the spectrum, various scholars voice their doubts about the prospects of adoptable energy. To illustrate, Justice et al. (2024) professed that the positive impacts of renewables on carbon emissions, notwithstanding, renewables initiatives do not significantly impact trade openness, indicating that renewables may operate in a vacuum of economic overarching goals. In addition, Yadav et al. (2024) address the paradox of foreign direct investment (FDI) and the consumption of renewables, suggesting that FDI does not always synergize with the objectives of renewables. Uzar (2020) also noted that there is a negative correlation between economic growth and the utilization of renewables which suggests some of the paradoxes between economic growth and the use of energy. It is clear from the foregoing that there are potential benefits from renewables, but the results of various economic indicators and the absence of strong institutions within which to renewables can operate, do fail to much across with renewables in an economy.

Interaction effect of economic complexity and institutional quality

Latif and Faridi (2023) also show in their research the long-term co-integration connection between foreign direct investments, financial development, economic growth and the environment as indicators proving that these variables are related in their effects on the environment. Also, Sajid et al. (2024) show that the complexity of the economy can lead to an increase in emissions and the effects vary due to the quality of the institutions. In China, emissions decreased due to the improvement of institutions, while in Pakistan, there was a contrary law. Moreover, Latif et al. (2023) studied the interaction between information and communication technology and the ecological quality of numerous countries including Brazil, China and South Africa and found significant relationships, while no such relationships were found in India and Russia. All these studies confirm the importance of the interaction of the economic indicators with the environment.

On the other hand, there are critiques of the interaction effect model providing evidence of its applicability and generalizability of findings. The studies mentioned are beneficial and highlight differences based on varying institutions, as in Sajid et al. (2024), where the same economic complexity produced different environment outcomes in China and Pakistan. This indicates the interaction effect may have its limitations in other countries and different economic structures. The absence of such effects in some countries, such as India and Russia, in Latif et al. (2023) raises concerns on the efficacy of the model to provide sufficient detail on the economic and environmental systems. Therefore, while the interaction effect model has its merits, the evidence suggests it is limited in providing sufficient context.

Environmental based Kuznets Curve and Economic Complexity

The Environmental Kuznets Curve (EKC) theory states that there is a direct correlation between a nation's economic growth and its environmental degradation and that this holds true until a turning point is reached, after which the degradation improves as economic growth continues. It includes studies of the group of countries by Latif and Faridi (2023) and Balsalbore et al. (2022) which study the complex relationship between economic growth and carbon emissions, which is found to have an inverted U relationship. The emissions growth of carbon emissions is found to be growing until a turning point is reached. The same relationship is found by Agozie et al. (2022) but this time involving foreign direct investment for the BRICS (Brazil, Russia, India, China, and South

Africa) countries. More research from Wen et al. (2021) presents a strong relationship between South Asia's globalization and economic growth along with population and carbon dioxide emissions. This further supports the correlation between economic growth and degradation.

However, the theory is not without its critics. There exists a vast body of research that critiques the theory and draws attention to its implications and areas of concern.

Critics argue that the EKC overlooks negative impacts of FDI (Foreign Direct Investment) in economically growing counties including South Africa, China, India, Russia, and Brazil that are experiencing negative environmental impacts (Agozie et al. 2022). Also, economically growing countries, due to the dependence on nonrenewable energy, experience increased emissions. This is supported in Wen et al. (2021). Latif and Faridi (2023) also argue that in some circumstances the financial market-based EKC (FM-EKC) is woefully inadequate and fails to explain the observed diversity of the relationship in non-trivial settings. This leads us to question the validity of the EKC in capturing the paradox of globalization and economic growth's environmental sustainability challenges.

Past studies have focused primarily on the relationship between economic complexity and the environment; however, these studies have not considered the various dimensions of this relationship. In addition to the analytical framework, the review of literature also aims to justify and explain the nature of this analysis. This study will adopt the economic complexity-based environmental Kuznets curve (ECx-EKC) to determine the counter point. In this study, economic complexity will be integrated with institutional quality to assess the quality of environment. Furthermore, a square term on economic complexity will be incorporated in the analysis. Economic complexity has been the dominant variable in the past studies as a proxy for development.

Data and Methodology

The objective of this study is to analyses the relationship between the ecological footprint of BRICS countries and the complexity of their economies and the amount of energy they consume, as well as the role that the quality of their institutions has in shaping this relationship. The environmental Kuznets curve hypothesis serves as the foundation for this investigation. The Environmental Kuznets Curve, often known as the EKC, is a theoretical relationship between a number of different measures of environmental degradation and the gross domestic product per capita. During the initial stages of economic expansion, there is an increase in pollutant emissions and a decrease in environmental quality. However, after the per capita income exceeds a particular threshold (which varies depending on the indicator), the pattern reverses, and economic growth leads to an improvement in environmental quality. From this, we may deduce that the relationship between per capita income and environmental damage, also known as emissions, is shaped like an inverted U shape. The Economic Knowledge Council (EKC) was named after Simon Kuznets, who proposed that the income gap widen and then narrows as economic development advances. (Wang, Q., Ren, F., & Li, R. 2024). The original environment Kuznets Curve function suggested the relationship between Carbon dioxide emission and economic development (Simon Kuznets 1995).

$$CO_2 = f(GG) \quad (1)$$

By following (Latif, N., & Faridi, M. Z. 2023.). We have incorporated economic complexity as an indicator of development and ecological footprints as a measure of environmental quality to form the modified EKC as:

$$ECF = f(ECx) \quad (2)$$

The econometrics form of equation ‘2’ can be written as:

$$ECF_{it} = \beta_0 ECF_{it-1} + \beta_1 ECX_{it} + \beta_2 IQI_{it} + \beta_3 ECn_{it} + \varepsilon_{it} \quad (3)$$

Equation ‘3’ established the linear relationship between economic complexity, energy consumption, institutional quality and environment. We have further modified the equation 3 to check the nonlinear affiliation among the selected variables in two different ways. As firstly we interested in to trace the moderating effect of institutional quality and economic complexity on environment. So, to check the interaction effect of economic complexity and institutional quality on environment by following the (Sajid, S., Abas, A., Hassan, S. S. U., & Arooj, M. (2024).) we can modified the equation 3 as:

$$ECF_{it} = \beta_0 ECF_{it-1} + \beta_1 ECX_{it} + \beta_2 IQI_{it} + \beta_3 ECn_{it} + \beta_4 ECX * IQI_{it} + \varepsilon_{it} \quad (4)$$

Secondly, by following the modified environmental Kuznets Curve (Youssef, A. B., Boubaker, S., & Omri, A. (2020).) we can derive the Environmental Kuznets Curve based on economic complexity (EKC-ECX) by using the squared term of Economic Complexity. So, the modified EKC equation based on economic complexity can be written as:

$$ECF_{it} = \beta_0 ECF_{it-1} + \beta_1 ECX_{it} + \beta_2 IQI_{it} + \beta_3 ECn_{it} + \beta_4 (ECX * IQI)_{it} + \beta_5 ECX_{it}^2 + \varepsilon_{it} \quad (5)$$

The description of all examined variables presented in table 1.

To examine empirically, we use a panel data set for the BRICS countries from 1991 to 2023. Different places are used to gather data for each category. As a dependent variable in this study, ecological footprints are used. As independent factors, economic complexity, institutional quality, foreign direct investment, and PCI are used. Atlas growth lab collects information about economic complexity. The world governance index is where the data on institutional quality comes from. Data on how much energy is used comes from the Energy Efficiency Index, and data on ecological footprints comes from the Global Footprint Network. World development indicators give us information on foreign direct investment and PCI.

The empirical research was conducted using 33 years of data from 1995 to 2023 for BRICS countries, which include Brazil, Russia, India, China, South Africa, and, according to the updated list, the United Arab Emirates and Iran. Egypt and Ethiopia are also part of the BRICS nations. Data was gathered from several sources in accordance with the model's variables. Economic complexity data is accessible from 1995 to 2021 for all selected nations. Ecological footprint data is available for several countries across different time periods. It was accessible from 1991 until 2022 for Brazil, India, Iran, China, and the United Arab Emirates. For Russia, the period is from 1991 to 2022; for Egypt, from 1991 to 2020; and for Ethiopia, from 1993 to 2022. Energy consumption data was available from 1991 to 2014 for all selected nations. PCI data was gathered from 1991 to 2023 for all nations. The data on FDI was not uniformly available, varying across different countries. Data for Brazil, India, China, Egypt, South Africa, and the United Arab Emirates was available from 1991 to 2023, while for Russia and Ethiopia, it was accessible from 1992 to 2023, and for Iran, it was gathered from 1993 to 2023.

Our dependent variable is Ecological Footprint, which is the best way to tell if the world is getting worse. The ecological footprint is a way to figure out how much people depend on natural resources. It is a way to figure out how many resources from the world are needed to run a certain business or way of life.

To put it more simply, the ecological footprint just shows how much stress people put on the natural resources around them (Wilson, J. 2024).

Most of the time, the ecological footprint is given in global hectares (gha). This helps experts figure out how much land each person needs to live.

Think of it as the need that people have and the quantity that nature provides. The ecological footprint is a popular way to figure out how sustainable something is, like a place, a person, or a business.

The amount of resources used is another way to say it. William Rees came up with the idea of calculating ecological footprints in 1992. The goal is to figure out how actions that people do affect the environment. When the Ecological Footprint guidelines were put in place in 2006, they said that the ecological footprint figures out how much biologically productive land is needed to provide people with the resources they need while also taking in greenhouse gas emissions.

Economic complexity, energy consumption, Institutional quality, foreign direct investment and PCI are our independent variable now we discuss in detail these variables.

Economic complexity

A country's economic complexity can be defined as the variety and level of sophistication of its productive output. In principle, it is a measurement of the knowledge and expertise that is surrounded within the economy of that country. According to this theory, the potential for economic expansion of a nation is directly proportional to the degree to which it can manufacture and export a diverse assortment of high-tech goods. To put it another way, it indicates the extent to which a nation is knowledgeable and capable, as demonstrated by the products and services that it generates (Ketu, I., & Ningaye, P. 2024).

There is a correlation between countries with higher degrees of economic complexity and faster and more sustainable economic growth. This is because these countries are better suited to innovate and adapt to changes in the global environment.

Energy consumption

The amount of energy that is consumed by various devices, appliances, and systems in order to carry out activities such as lighting, heating, and cooling, as well as powering machines, is referred to as energy consumption (Meng, H., Feng, S., & Li, C. 2024). Kilowatt-hours (kWh) are the units using which it is measured, and it is an essential component in the process of estimating operational costs. By gaining an understanding of energy use, one can identify areas that could benefit from efficiency improvements and reduce their influence on the environment.

Institutional quality

The word "institutional quality" relates to the effectiveness and trustworthiness of an organization's rules, laws, and customs. These characteristics have a significant impact on the organization's ability to operate efficiently and achieve its goals. These factors have a considerable impact on the organization's capacity to function efficiently and complete its objectives (Khan, H., Dong, Y., Bibi, R., & Khan, I. 2024). A high level of institutional quality is absolutely necessary for the advancement of social progress, political stability, and economic growth. Many other factors, such as the rule of law, corruption, and governance, are included in its scope, and it is frequently evaluated with the help of metrics such as the Worldwide Governance metrics developed by the World Bank.

Foreign direct investment

An investment that is considered to be FDI that is the purchase of an asset in a different nation in such a way that the purchaser is granted direct control over the asset (Zwartkruis, W.2024).

The term "foreign direct investment" (FDI) refers to a significant and long-term investment that is made by a government or a financial institution into a foreign enterprise. Foreign direct investment (FDI) investors typically take control of domestic enterprises or joint ventures and actively participate in their operations.

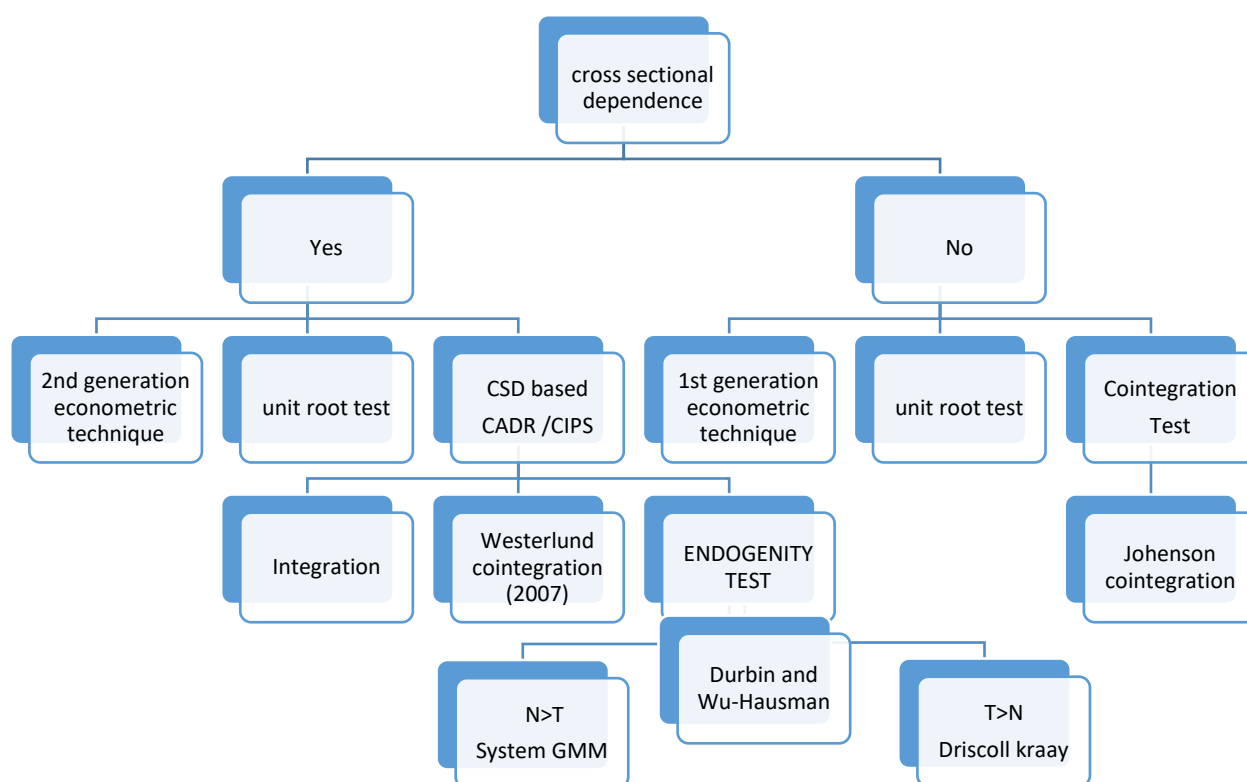
Per capita income

A measure of the average income earned by each individual in a certain region or country is referred to as the per capita income, which is also referred to as the average income. The formula for determining it is to divide the total revenue of a region by the population of that region.

The per capita income is a method that is utilized to ascertain the average income per person for a region, as well as to assess the quality of life and level of living of the people (Maslov, G. A., & Sherstobitova, Y. A. 2024).

Methodological Roadmap

To estimate the suggested relationship the following roadmap is used. According to this flow chart the first step is to check for the cross-sectional dependence as it will further guide us to proceed with 1st generation or 2nd generation econometric techniques.



Cross sectional dependence (CSD)

Cross-sectional dependence test is utilized in panel data analysis in order to determine whether or not the cross-sectional units (like people, businesses, and countries) are dependent on each other. This test checks whether the error terms or factors between units are linked.

Our results of cross-sectional dependence test are positive, so we proceed to second generation test.

Second generation test

The term "second-generation tests" is used in the field of econometrics to refer to panel data unit root and cointegration tests. These tests take into consideration cross-sectional dependence among panel units (such as countries, enterprises, and so on), which is something that first-generation tests normally neglect.

Tests of the second generation were created to address the issue of CSD which, if disregarded, can result in results that are biased or may be deceptive.

We use Pesaran's CADF and CIPS tests

CADF is Cross-sectional based Augmented Dickey-Fuller.

CIPS is Cross-sectional based Im-Pesaran-Shin.

The results of these tests allow us to move forward with our investigation.

Unit root test

To determine if a time series variable is unstable and has a unit root, statisticians use a unit root test. If the meaning and variance of a time series change during the course of the data, we say that it is non-stationary since the series has a unit root. It is crucial to bear this in mind while working with time series data and econometrics, particularly when developing models or forecasts.

Integration

Integration is a term that is commonly used in the field of econometrics to refer to the concept of stationarity and unit roots pertaining to time series analysis.

In this particular setting, integration refers to the question of whether or not a time series is stationary or non-stationary. To check the cointegration among the variables we employ Wester Lund cointegration test.

Endogeneity

In the fields of statistics and econometrics, the term "endogeneity" is used to describe a situation in which an explanatory variable associated with a model is shown to have a correlation with the error term. In order to investigate the issue of endogeneity, the tests developed by Durbin-Chie and Wu-Hausman were utilized.

Our investigation revealed that the time period, denoted by T , is bigger than the number of countries, denoted by N . As a result, we shifted our focus to the Driscoll kraay test. In the opposite scenario, the GMM system was utilized, but we utilized the Driscoll kraay test to determine our ultimate outcomes.

Empirical Findings and Discussion

The results of an empirical study of economic complexity, ecological footprint, institutional quality and environmental quality for the case of BRICS countries from 1995 to 2022 is explained in this chapter of the study. Statistical and econometric techniques are also stated in this chapter. The results is obtained using the econometric technique of Driscoll kraay method.

Statistical Analysis

We discuss the descriptive analysis and correlation matrix of the chosen variables in this chapter. In descriptive analysis we address the mean median minimum maximum standard deviation,

skewness, kurtosis, Jarque Bera, probability and also discuss sum and sum of square deviations of the data. It is a method of collecting data with the intention of producing information that is helpful within the context of a certain subject. It is necessary to have data sources that are both relevant and valid in order to arrive at findings that are both useful and efficient.

Descriptive Statistics

Table 5.1 describes the descriptive analysis of the study's relevant variables. This study spans the years 1995 to 2022 and focusses on the BRICS countries. According to summary statistics, the ecological footprint (ECF) has a mean of 2.033861 and a median of 1.578437 maximum value. 7.546647 is the minimum value of 0.379946 for the standard deviation. 1.808421 skewness 1.673519 kurtosis 4.93729, while JB = 106.5598, sum and sum of square dev. = 347.7903 and 555.9659, respectively. Energy consumption (ECN) has a mean of 178.9792, median is 154.5891, and maximum value 610.5412 Mini Value The standard deviation of 55.63852 is 121.3703, the skewness and kurtosis are 2.012182 and 2.012182, respectively, and the value of JB is 233.1021; the sum and sum of square dev. are 30605.45 and 2504226. .Economic complexity (ECx) has a mean of -0.02548, a median of 0.126792, a maximum of 1.316443, a minimum of -1.32325, a standard deviation of 0.619938, skewness and kurtosis of -0.33274 and 2.41325, and a JB value of 5.608396, sum and sum of squares dev. of -4.35769 and 65.33488. Foreign Direct Investment (FDI) has the mean 2.200174, with a median of 1.842379. The maximum value is 9.348567, and the minimum value is -1.16684 standard deviation. 1.752437 skewness and kurtosis are 1.074915 and 4.619472, respectively. The value of JB is 51.61674, the sum is 376.2297, and the sum of std dev. is 522. 0758. The mean and median values for institutional quality (IQI) are -0.04472 and 0.093484, respectively, and the maximum and minimum values are 3.218522 and -4.29216, with a standard deviation of 1.902416. Skewness and kurtosis are -0.26965 and 2.536116, respectively, and the value of JB is 3.605551. The sum and sum of square dev. are -7.64671 and 615.2619. Per capita income (PCI) has a mean value of 3.116829 median is 3.242901 max and mini values are 13.63582 and -17.1454 std.dev of PCI is 4.579689 while skewness and kurtosis are -1.08383 and 5.914915 value of JB is 94.01 , sum and sum of square dev. is 532.9778 and 3565.503.

Table 5.1: Descriptive Statistics (dependent variable environmental quality)

	<i>ECF</i>	<i>ECN</i>	<i>ECX</i>	<i>FDI</i>	<i>IQI</i>	<i>PCI</i>
<i>Mean</i>	2.033861	178.9792	-0.02548	2.200174	-0.04472	3.116829
<i>Median</i>	1.578437	154.5891	0.126792	1.842379	0.093484	3.242901
<i>Maximum</i>	7.546647	610.5412	1.316443	9.348567	3.218522	13.63582
<i>Minimum</i>	0.379946	55.63852	-1.32325	-1.16684	-4.29216	-17.1454
<i>Std. Dev.</i>	1.808421	121.3703	0.619938	1.752437	1.902416	4.579689
<i>Skewness</i>	1.673519	2.012182	-0.33274	1.074915	-0.26965	-1.08383
<i>Kurtosis</i>	4.93729	2.012182	2.41325	4.619472	2.536116	5.914915
<i>Jarque-Bera</i>	106.5598	233.1021	5.608396	51.61674	3.605551	94.01791
<i>Probability</i>	0	0	0.060555	0	0.164841	0
<i>Sum</i>	347.7903	30605.45	-4.35769	376.2297	-7.64671	532.9778
<i>Sum Sq. Dev.</i>	555.9659	2504226	65.33488	522.0758	615.2619	3565.503

Source: Estimation are carried out with the help of E. view 9(Author's calculations)

According to our results the variables ecological footprint (ECF), energy consumption (ECN) and foreign direct investment (FDI) are positively skewed while the other variable are negatively skewed due to their negative values according to our results. When we discuss about the results of

kurtosis then the variables ecological footprint (ECF), economic complexity (ECX) and per capita income (PCI) these variables are showing the leptokurtic behavior because the value of kurtosis is greater than three while other variables are showing the platykurtic behavior value of kurtosis of all these variable is less than three. According to JB statistics the level of significant is greater than five percent of all variables it means all variables are normally distributed so we can proceed further long run estimation.

Correlation Matrix

To check the problem of multicollinearity we conducted the correlation analysis the results of correlation matrix are presented in table 5.2

Table 5.2: Correlation Matrix

	<i>ECF</i>	<i>ECN</i>	<i>ECX</i>	<i>FDI</i>	<i>IQI</i>	<i>PCI</i>
<i>ECF</i>	1					
<i>ECN</i>	-0.26435	1				
<i>ECX</i>	0.7459	-0.46736	1			
<i>FDI</i>	0.022754	0.023359	0.203955	1		
<i>IQI</i>	0.443467	-0.65005	0.477236	-0.00296	1	
<i>PCI</i>	-0.41954	0.153337	0.198556	0.170832	-0.30198	1

Estimation is carried out with the help of E-view 9(Author's calculation)

The correlation matrix for the variables is shown in the table above. The correlation matrix results show that there is a weak correlation between ECF and ECN, FDI, IQI, and PCI. The correlation between ECF and ECX is strong. ECN is negatively correlated with IQI and ECX. Economic complexity has a moderate correlation with FDI, IQI, and PCI. IQI is negatively correlated with both FDI and PCI. There is no multicollinearity between the variables.

Cross Sectional Dependence Test

Next to proceed further to choose among the first generation and second generation econometric technique it is important to check the cross sectional dependence among the selected countries. To check the cross sectional dependence test for our panel data set we apply the following tests in table 5.3

Table 5.3: Cross sectional dependence test

<i>Test</i>	<i>Statistic</i>	<i>d.f.</i>	<i>Prob.</i>
<i>Breusch-Pagan LM</i>	95.87547	36	0.0000
<i>Pesaran scaled LM</i>	7.056391		0.0000
<i>Pesaran CD</i>	4.231024		0.0000

Findings indicate that cross-sectional dependence exists among countries. Consequently, we are unable to proceed with the first generation test and should instead implement the second generation test.

To check the stationarity of the variables we employ cross sectional Im-pesaran-shin test and cross sectional Augmented Dickey -Fuller test the results of these tests are presenting in table 5.4.

Table 5.4: CSD-Based Unit Root Test

Variable	Test	At Level	At First Difference
<i>ECF</i>	CIPS	-1.52	-6.13*
	CADF	-2.13	-5.32*
<i>ECX</i>	CIPS	-1.17	-7.35*
	CADF	-2.38	-6.28*
<i>IQI</i>	CIPS	-2.12*	-8.21*
	CADF	1.29	-7.48*
<i>ECN</i>	CIPS	-2.91*	-6.32*
	CADF	1.19	-5.27*

As per CSD-based unit root test, all variables are non-stationary at the level. Consequently, after taking the first difference, all variables become stationary, and all variables are significant at the first difference.

Therefore to check the cointegration among the selected variables we employ wester Lund cointegration test and results of wester Lund cointegration test are presenting in table 5.5.

Table 5.5: Wester Lund Cointegration

Statistics	Values	Probability
Gt	-3.86	0.000
Ga	-7.23	0.020
Pt	-13.68	0.001
Pa	-7.25	0.082

According to wester Lund cointegration test three out of four statistics suggested the existence of the long run relationship between the selected variables.

To check the problem of endogeneity the tests of Durbin χ^2 and Wu –Hausman applied the results of these tests are presented in table 5.6.

Table 5.6: Endogeneity test

Endogeneity Test		
Test	Statistics	Decision
Durbin (χ^2)	47.16*	Rejection of Null hypothesis (Endogeneity)
Wu-Hausman (F-Statistics)	41.16*	Rejection of Null hypothesis (Endogeneity)

Results are significant suggesting the rejection of Null hypothesis meaning that there is an existence of endogeneity problem among the explanatory variables with the error term. Based on the pre estimation diagnostics the best technique that we have applied to estimate the coefficient is Driscoll and Kraay standard error method. Results of Driscoll and Kraay standard error test are presented in table 5.7.

Table 5.7: Driscoll – Kraay Test Result

Variable	Model 1	Model 2	Model 3
<i>ECF_lag1</i>	0.87*	0.86*	0.88*
<i>ECX</i>	-0.05*	-0.04*	-0.01*
<i>ECN</i>	0.14**	0.16*	0.12**
<i>IQI</i>	-0.03*	-0.02*	-0.03*
<i>PCI</i>	0.02	0.03*	0.01*
<i>FDI</i>	0.07*	0.06**	0.08*
<i>ECX × IQI</i>	—	-0.04*	—
<i>ECX²</i>	—	—	0.020*
<i>Turning Point</i>	—	—	0.739

Table 5.7 is divided in to three columns. Column 1 represented the results of model 1 where we established the liner relationship between economic complexity, institutional quality and ecological footprint. Column 2 represented the results of model 2 where we established the interaction effect of economic complexity and institutional quality on ecological footprint .while third Column established square term relationship to check the shape of environmental Kuznets curve based on economic complexity.

The Driscoll-Kraay regression results, presented across three model specifications, provide comprehensive insights into the dynamic determinants of environmental quality (ECF). The lagged dependent variable (*ECF_lag1*) shows a strong and statistically significant positive coefficient 0.87, suggesting high persistence in environmental quality, and meaning that current conditions are heavily influenced by past states. The presence of the inertia effect can be considered proven.

The findings of our analysis indicate that there is a connection that is in the other direction between the degree of economic complexity and the existence of an ecological footprint. This is because a change of 1 unit in economic complexity leads in a reduction of 0.05 units in ecological footprint. This is the reason underlying this phenomenon. This is because economies that are more complex are better able to develop and adopt cleaner technologies, which ultimately leads in a reduction in their ecological footprint. More complex economies are also better equipped to reduce their environmental impact. The tendency of more developed countries to participate in renewable energy sources and other environmentally friendly activities, which can assist reduce the negative impact that energy production and use have on the environment, may contribute to the reduction of environmental impact. The reason for this is that these investments have the potential to assist in reducing the quantity of energy that is produced and utilized. The results of our investigation are justified on the base of these research (Balsalobre-Lorente, et al, 2024, Kılıç, C.,et al,2024).

A one-unit increase in energy consumption results in a 0.14-unit rise in ecological footprint, according to the findings of our model, which indicates that there is a positive association between energy consumption and ecological footprint. The destruction of the ecosystem or the creation of a greater ecological imprint is the result of high energy use. Emissions have increased as a result of increased energy consumption through activities such as the burning of fossil fuels for the generation of energy, which emits greenhouse gases such as carbon dioxide and contributes to climate change as well as other environmental problems. Extraction of energy, such as coal mining, contributes to an increase in the amount of pollutants in the country. These studies provide the foundation upon which our findings from the investigation may be justified (Georgescu, I.et al 2024, Fan, et al. 2024,).

The positive impact of institutional quality (IQI) on ecological footprint (ECF) reaffirms the significance of governance and policy implementation in environmental preservation. There is a correlation between a change of 1 unit in the quality of the institution and an improvement of 0.03 units in the quality of the environment, as indicated by the data that we acquired from model 1. Further proof of the IQI's importance, this information shows how it has helped lessen the country's ecological footprint in government. Strong national institutions play a crucial role in improving environmental quality by implementing various frameworks for protecting the country's biodiversity. It should come as no surprise that the results of our investigation are corroborated by the findings of this other research which was conducted (Uzar, U. 2021, Hasan, m. et al, 2024).

The pollution haven theory is validated by the fact that (FDI) has been shown to have a favorable impact, indicating that outside financing may worsen environmental quality. PHEH claims that polluting enterprises are found in nations with laxer environmental laws. The construction of polluting facilities in nations may result from FDI. One of the main causes of these industries moving and the worsening of the environment is FDI. Based on our findings, there is a 0.07 unit increase in environmental degradation for every unit shift in FDI. These studies provide support for our findings (Musah, M.et al, 2022, Ekesiobi, C., et al, 2024).

PCI demonstrates a natural impact on the ecological footprint across all three scenarios.

We added the interaction effect of economic complexity and institutional quality on ecological footprint in model 2, which presented the results of our investigation. In this section, we will analyze the results of the interaction term between economic complexity and institutional quality. The results of the other variables are the same as those that we explained earlier. Direction of the results these variables are same, but strength of results is different in both models. Economic complexity and institutional quality both improve the ecological footprint individually. When we investigate the interaction of both IQI and ECX which also helps to improve the environmental quality. There is a negative and significant interaction term ($ECX \times IQI$) in Model 2 -0.04 , which indicates that good institutions can improve the harmful consequences of environmental externalities. Furthermore, this interaction term is negative. The interaction between the complexity of the economy and the quality of the institutions contributes to the improvement of the environmental degradation.

In model 3, we incorporated the squared term of economic complexity, which illustrates the inverted U-shaped (EKC) based on economic complexity (ECX-EKC). This model identifies a turning point at 0.739, beyond which economic complexity begins to elevate the ecological footprint, resulting in increased environmental degradation following this threshold in our analysis.

Conclusion and Policy Recommendations

This part summarizes the author's investigation. To wrap up, we have made arguably the first strides in understanding the connection between economic complexity and the environment in the case of the BRICS. Based on the Environmental Kuznets Curve (EKC) theory, we showed that economic complexity is initially positively correlated with, and at some point changes, to an increase in, ecological footprints, and that an inflection point exists with additional economic complexity that is positively correlated with ecological health. Based on the results of the study, we argue that economic complexity and ecological footprints have an inverse relationship, as economically complex countries are more capable of implementing environmentally friendly technologies, and as such, do less environmental harm.

In addition, we also showed that the consumption of energy fuels environmentally harmful and economically unsustainable activities, therefore the transition to low emissions, sustainable energy

is part of the solution to climate change. We also discussed the importance of institutional quality, demonstrating that greater quality of institutions is positively related to environment. We also explained that foreign direct investment (FDI) is consistent with a decline in environment and supports the pollution theory.

Our findings suggest that BRICS countries be proactive in policy implementation concerning monitoring and managing export capacities, investing in cleaner technologies, and shifting to renewable energies. Enhancement of institutional frameworks should foster and support sustainable economic complexity and the protection of the environment. Policymakers should be oriented to rural development so as to relieve urban congestion and the concomitant overcrowding of its environment.

In the future, we propose that more emphasis be placed on the construction of a CEPI (Complexity-Environment Performance Index) to reflect more accurately the interrelationship between economic complexity and the environment. This should then lead to the examination of the role of renewable energies alongside other more critical factors of human capital and natural resources. The focus of developing asymmetry and non-linearity between the said factors should lead to more meaningful results. The extent of future studies should be limited by the volume of available data. The more data that will be accumulated, the greater will be the understanding of the relationship between the environment and economic complexity.

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