

DOES ECONOMIC COMPLEXITY INFLUENCE CARBON EMISSIONS? EVIDENCE FROM NEXT ELEVEN COUNTRIES

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Abstract

Research Purpose: The study examines the effect of economic complexity on carbon dioxide emissions in the Next 11 countries with the view to validate or refute the economic complexity-Kuznets curve (E_cKC) between 1995 and 2019. The Next 11 countries include Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey, and Vietnam.

Design/Methodology/Approach: Two econometric methods, correlated Panel standard error (PCSE) and feasible generalized least squares (FGLS) estimating techniques, are used to achieve the objectives of the study.

Findings: The estimates from the FGLS approach are consistent with that of the PCSE approach. The results from both techniques show that economic complexity increases carbon emissions in the Next 11 countries. Also, from the E_cKC , the study invalidates the hypothesis and supports a positive monotonic linear relationship between economic complexity and carbon emissions, which also means the "*pollution haven hypothesis*".

Originality/Value/Practical Implications: The study examines whether the environmental Kuznets curve (EKC) in the Next 11 countries is valid or not. To do this, the current study is different from earlier studies in that it uses economic complexity—that is, the economic complexity-Kuznets Curve (E_cKC)—instead of GDP. This is explained by the fact that environmental issues should involve the development of more advanced commodities rather than just raising an economy's GDP productivity. And most of the countries in the Next 11 countries are currently shifting their economies to produce more complex goods.

Keywords: economic complexity, carbon dioxide emissions, Next 11 countries, PCSE, FGLS.

JEL Classification: C21, O10, O3, O44.

Introduction

One significant obstacle to achieving sustainable development in the modern era is the effects of global climate change. NASA (2023) stated that carbon dioxide is a substantial heat-trapping gas, also called greenhouse gas, that is generated by the exploitation and burning of fossil fuels, such as oil, coal, or natural gas, as well as during wildfires and natural events like volcanic eruptions. Furthermore, in less than 200 years, human activity has increased the amount of carbon dioxide in the atmosphere by 50 per cent. Thus, to reduce carbon dioxide (CO_2) emissions and promote sustainable economic growth globally, the seventh Sustainable Development Goal (SDG 7) intends to provide access to inexpensive, dependable, and clean energy sources (Murshed et al., 2022a).

It is argued that the economy will be affected environmentally when agricultural products are replaced by more sophisticated (complex) products, as this will require the introduction of new technologies and higher levels of capital intensity. This is supported by Incekara (2019) and Can and Gozgor (2017) that economies undergo a transition from being "energy-intensive" to being "technology-intensive". Satrovic and Adedoyin (2022) asserted that whereas more complex countries degrade the environment excessively, lesser complex countries often generate agricultural products and cause less environmental damage. However, the world's most advanced economies have improved their technological capabilities and adopted greener practices (Yilanci & Pata 2020). The most advanced complex economies have less

environmental deterioration as a result of clean production technologies. Therefore, one of the variables influencing environmental quality is thought to be economic complexity. Developed by Hidalgo and Hausmann (2009), “the Economic Complexity Index (ECI) measures the complexity of a nation's production by perceiving trade data as a bipartite network (ubiquity and variety) that connects nations to the goods they export”. This suggests that economic complexity is more strictly linked to the quality of production, while economic growth (as mostly measured by gross domestic product, GDP) is related to the quantity of production (Laverde-Rojas et al., 2021). Furthermore, Osinubi and Ajide (2022) reaffirmed that the economic system's capacity and production structure are related to economic complexity. It illustrates how economic agents acquire knowledge through their activities during the production process (Ajide, 2022; Nguyen et al., 2021).

The Next 11 countries are not left out in the effort to meet SDG 13's goal of improving environmental quality. These nations have a strong chance of overtaking the BRICs countries to become the major economies in the world in the twenty-first century, according to Goldman Sachs Investment Bank's analysis following the formation of the BRICs in 2003. According to Yu et al. (2022), the countries are trying to expand their trade partners and boost their exports while they are in a transitional phase. Given this, it is argued that the Next 11 countries with their growing economies will be accompanied by increased energy consumption. Environmental problems will also start to surface as economies become less energy-efficient and more industry-focused to spur economic growth. Nonetheless, a few countries—most notably Nigeria and Mexico—are improving their energy productivity to lessen their impact on the environment (Goldman Sachs, 2015). Carbon emissions rise in tandem with economic expansion and rising energy use. Global efforts to reduce carbon emissions will be crucial because in 2004 the BRIC and Next 11 countries contributed more to carbon emissions than the developed countries. This is hardly surprising given that South Korea, Indonesia, and Iran rank among the top energy-consuming nations worldwide in 2019 (Enerdata, 2023). The implication is that these countries will continue to experience poor environmental quality through their energy sources and use if adequate measures are not put in place (Yu et al., 2022).

Empirical research has demonstrated that environmental deterioration can be exacerbated (Dogan et al., 2019; Neagu & Teodoru, 2019) or decreased (Kirikkaleli et al., 2023; Lee & Olasehinde-Williams, 2022; Yu et al., 2022; Boleti et al., 2021; Can & Gozgor, 2017) by economic complexity. The variant in the results enables us to examine how economic complexity will affect environmental degradation (carbon emissions) in the Next 11 countries. Deviating from extant studies, this present study advances knowledge, especially in the area of economic complexity and environmental deterioration, in two ways. First, given the economic potential of these countries to become the largest economies in the world in the 21st century, it is essential to understand how economic complexity affects carbon emissions in the Next 11 countries as studies in these areas did not specifically focus on the selected countries. The United States Energy Information Administration (EIA, 2012) estimates that the Next 11 countries are responsible for around 10% of the world's carbon emissions, which provides a rationale for this.

In addition, considering each country's share of global carbon emissions, the study examines whether the environmental Kuznets curve (EKC) in the Next 11 countries is valid or not. To do this, the current study is different from earlier studies in that it uses economic complexity—that is, the economic complexity-Kuznets curve (E_cKC)—instead of GDP. This is explained by the fact that environmental issues should involve the development of more advanced commodities rather than just raising an economy's GDP (gross domestic product) productivity. And most of the countries in the Next 11 countries are currently shifting their economies to produce more complex goods. It is expedient to establish whether environmental degradation (carbon emissions) will rise at first and then fall as economic complexity rises. Specifically, this presents the deviation of this study from Yu et al. (2022) who used economic growth to test the economic growth-Kuznet curve (EKC) in the Next 11 countries. However, because of their expanding economies, policymakers and government officials would find the study's findings and conclusions helpful in determining what steps to take to reduce environmental deterioration (carbon emissions). It is on this note that the present study seeks to examine the effect of economic complexity on carbon emissions in the Next 11 countries, with the view to investigating the validity or otherwise of the environmental Kuznets hypothesis. This becomes important because the Next 11 countries are trying to increase their exports and their growing economies would be

accompanied by increased energy consumption that could lead to increased carbon emissions. The study employs both correlated Panel standard error (PCSE) and feasible generalized least squares (FGLS) approaches to achieve the stated objectives. The results from both techniques show that economic complexity increases carbon emissions in the Next 11 countries. Also, from the E_cKC, the study invalidates the hypothesis and supports a positive monotonic linear relationship between economic complexity and carbon emissions, which also means the "*pollution haven hypothesis*".

The remaining part of this paper is structured as follows. The second section, which discusses the previous research on the topic, comes after this section. Section Three describes the study's methodology in detail, whereas Section Four concentrates on the results and a discussion of the findings. Finally, the study's findings and possible recommendations are provided in Section Five.

Literature Review

Overview of Economic Complexity and Carbon Emissions in the Next 11 Countries

Figure 1 shows that the countries are progressively producing more advanced goods, as the ECI indicates a positive trend. To be more precise, the countries have a negative ECI from 1995 to 2011, whereas the next 11 countries have a positive ECI from 2012 onward. This could be one of the reasons why the countries are classified as the next emerging economies. In specifics, as shown in Figure 1, the Next 11 countries have an average ECI between -0.3842 and 0.108 for the years 1995 to 2019, suggesting that these nations are already transitioning to producing complex goods. Figure 2 illustrates how the countries emit large amounts of carbon dioxide into the atmosphere, which is thought to have negative effects on both the economy and public health. The carbon emissions chart illustrates how greenhouse gas emissions in the Next 11 countries have been rising over time. Precisely, these countries' average carbon emissions per capita fall between 2.248 and 3.549 metric tons. This implies that the countries are experiencing a high level of environmental pollution which has to be reduced in line with the Paris Agreement as contained in Yu et al. (2022). However, studies (Paramati et al., 2017; Shahbaz et al., 2016; Yildirim et al., 2014) revealed that the Next 11 countries are now in the course of energy conservation and preserving the environment.

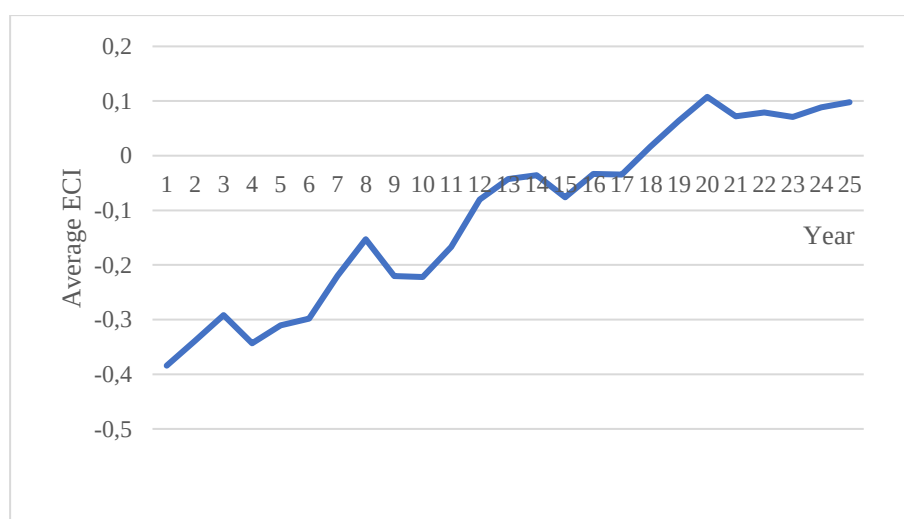


Fig. 1: Average economic complexity (ECI) in Next 11 countries (Source: Author's computations)

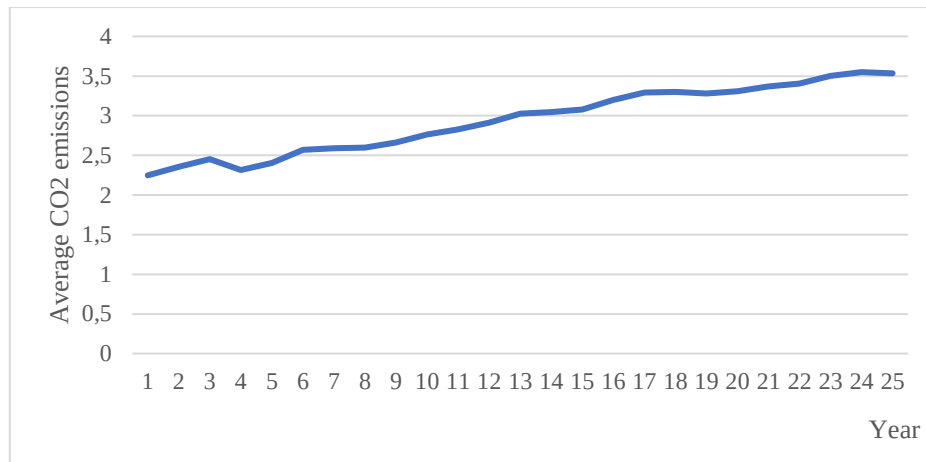


Fig.2: Average carbon dioxide emissions (CO₂) in Next 11 countries (Source: Author's computations)

Empirical Review

The literature is replete with proof that global warming brought on by humans is currently occurring. The topic of economic growth and environmental quality appears frequently in the literature, to determine whether or not the environmental Kuznets hypothesis (EKC) is valid. While some studies (Balsalobre-Lorente et al., 2023; Can & Gozgor, 2017; Kılıç et al., 2023; Kirikkaleli et al., 2023; Neagu, 2019; Satrovic & Adedoyin, 2022) accepted the hypothesis, others which include Gill et al. (2018), Laverde-Rojas et al. (2021), Xu (2018), and Zoundi (2017), rejected the hypothesis. The gross domestic product (GDP) was utilised as a proxy for economic growth in the majority of research that examined the EKC hypothesis. Environmental issues, however, extend beyond a rise in production. For this reason, the problem of economic complexity is raised. The literature has recently begun to pay more attention to this relationship. Amongst the few studies are Balsalobre-Lorente et al. (2023), Kazemzadeh et al. (2022), Murshed et al. (2022b), Satrovic and Adedoyin (2022), and Yu et al. (2022).

Rather than utilising GDP as a measure of economic growth to verify the EKC hypothesis in the BRICS nations, Balsalobre-Lorente employed ECI to examine the EKC hypothesis, with the findings that the E_cKC hypothesis is valid in the selected countries. This means that at the initial stages, carbon emissions rise as the BRICS nations produce more sophisticated commodities, but they subsequently fall as the nations' economies get more complicated (Neagu, 2019). In contrast, Yu et al. (2022) employed GDP for the EKC hypothesis in the Next 11 countries. The analysis validates the U-shaped relationship between economic growth and environmental degradation but rejects the EKC in the Next 11 countries. Economic complexity exacerbates the ecological footprint in low quantiles (10th), becomes insignificant in the 25th quantile, and diminishes the ecological footprint in higher quantiles, according to Kazemzadeh et al. (2022) who used panel quantile regression. Similarly, Boleti et al. (2021) used a world sample (88 developing and developed countries) to establish that economic complexity increases environmental performance in the countries and also rejected the EKC hypothesis. However, the finding shows a monotonic positive relationship between economic growth and carbon emission.

Additionally, Kılıç et al. (2023) showed that in the selected industrialised countries, economic complexity significantly worsens environmental degradation. The African continent has also been quite concerned about the issue of environmental quality. Abdi (2023) concentrated on 41 nations in sub-Saharan Africa to investigate how economic complexity affects environmental quality. The study used pooled mean group (PMG) cointegration analysis to prove that environmental quality is only positively impacted by economic complexity in the long run.

In single-country studies, Laverde-Rojas et al. (2021), employing different techniques, reported a significant positive association between ECI and carbon emissions in Colombia. This contradicts Can and Gozgor (2017) who found that raising a nation's productive sophistication can spur environmental quality in France. This finding suggests that nations with high ECI are likely to invest consistently more in cleaner technologies since they are concerned about their high non-renewable energy consumption.

In Turkey, Kirikkaleli et al. (2023) argued that economic complexity reduces environmental quality with different methods of estimation. Also, Shahbaz et al. (2016) revealed that economic complexity spurs ecological footprint in the United States. Several studies have demonstrated the presence of a feedback effect between economic complexity and ecological footprint or environmental quality in addition to the unidirectional relationship between the two. These studies are Abdi (2023), Saqib et al. (2023), Satrovic and Adedoyin (2022), Shahzad et al. (2021).

In conclusion, the examined studies have shown that the association between economic complexity and carbon dioxide emissions is contradictory. Contributing to the literature, especially in the context of the Next 11 countries, the current study advances our understanding of the subject matter. Based on our knowledge, this study is one of its kind to test the economic complexity-Kuznets hypothesis in the Next 11 countries. Additionally, by using the Correlated Panel Standard Error (PCSE) estimating technique, the study closes a methodological gap and allows us to investigate how economic complexity affects carbon dioxide emissions when cross-sectional dependence, slope heterogeneity, heteroscedasticity, and serial correlation are present. Also, the study employs Feasible Generalised Least Square (FGLS) regression to perform robustness assessments. Based on this, the following hypotheses are tested:

Hypothesis 1: Economic complexity influences carbon emissions in the Next 11 countries.

Hypothesis 2: Environmental Kuznets hypothesis, using economic complexity, holds in the Next 11 countries.

Research Methodology

Data

The study examines the effects of economic complexity on carbon emissions in the Next 11 countries between 1995 and 2019 based on data availability. The countries are Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey, and Vietnam. The countries are chosen because of their growing economies accompanied by increased energy consumption, which in turn, can influence environmental degradation. The variables employed include economic complexity index (ECI) obtained from MIT's Observatory of Economic Complexity (<https://atlas.media.mit.edu>), carbon dioxide (CO₂) emissions (metric tons per capita), GDP per capita (constant 2015 US\$), urban population (URP) and renewable energy consumption (% of total final energy consumption, {REN}) gotten from the World Bank's World Development Indicators (<https://data.worldbank.org/indicator>). Except for GDP per capita and urban population, which are converted to a logarithmic form to reduce series instability, other variables are utilised in their level form. More importantly, the results of this study are obtained from STATA 15.

Model Specification and Estimation Technique

Following Balsalobre-Lorente et al. (2023) and the economic complexity-Kuznets curve rather than the economic growth-Kuznets curve, equation 1 presents the empirical model that will be used to accomplish the objectives of the study.

$$CO_{2it} = \psi + \lambda_1 ECI_{it} + \lambda_2 ECI_{it}^2 + \lambda_3 LGDP_{it} + X'_{it}\gamma + \varepsilon_{it} \quad (1)$$

where CO₂ is carbon dioxide emissions, ECI and ECI² denote economic complexity and square of economic complexity, LGDP is the log of gross domestic product per capita, "t" represents the study period, "i" indicates the Next 11 countries. X is a vector of control variables, which include urban population (URP) and renewable energy (REN). The inclusion of urban population and renewable energy is guided by the existing literature (Abdi, 2023; Balsalobre-Lorente et al., 2023; Hsu, 2021; Laverde-Rojas et al., 2021; Saqib et al., 2023; Szetela et al., 2022). In simple terms, we expect λ_4 and λ_5 to be positive and negative, respectively, as shown in Equation 2. Thus, equation 1 can be rewritten to include the control variables as shown in equation 2.

$$CO_{2it} = \psi + \lambda_1 ECI_{it} + \lambda_2 ECI_{it}^2 + \lambda_3 LGDP_{it} + \lambda_4 LURP_{it} + \lambda_5 REN_{it} + \varepsilon_{it} \quad (2)$$

where ψ is the constant term, $\lambda_1, \dots, \lambda_5$ indicate the coefficients of economic complexity, a square of economic complexity, a log of gross domestic product per capita, a log of urban population, and renewable energy, respectively. ε_{it} is the error term. To accept the E_cKC (economic complexity-Kuznets) hypothesis, we expect λ_1 and λ_2 to be significantly positive and negative, respectively (that is, $\lambda_1 > 0, \lambda_2 < 0$, indicating an inverted U-shaped association). The economic complexity turning point of this curve is calculated as $\hat{\pi} = 0.5 \frac{\hat{\lambda}_1}{\hat{\lambda}_2}$. Contrarily, we have a U-shaped association if $\lambda_1 < 0, \lambda_2 > 0$. Also, $\lambda_1 < 0, \lambda_2 < 0$ denotes a monotonically decreasing linear association, while $\lambda_1 > 0, \lambda_2 > 0$ denotes a monotonically increasing linear relationship. λ_1 should be negative if the countries are to benefit from economic complexity through reductions in environmental degradation (CO_2 emissions). The turning point ($\hat{\pi}$) is obtained by finding the derivative of equation 2 with respect to economic complexity (ECI).

The study employs the Corrected Panel Standard Error (PCSE) approach and Feasible Generalized Least Squares Regression (FGLS) method for a robustness check on equation 2. This PCSE method is useful because it accounts for cross-sectional dependence, slope heterogeneity, heteroscedasticity, and serial correlation, and it is useful when the number of cross-sections is below the study period, that is $N < T$. The null hypothesis of cross-sectional independence can be rejected at 1%, 5% or 10% levels of significance. The CSD test is given below in Equation 3.

$$CD = \sqrt{\frac{2T}{N(N-1)}} (\sum_{i=1}^{N-1} \sum_{j=i+1}^N \hat{\vartheta}_{i,j}) \quad (3)$$

Where N and T denote cross-sections and time. $\hat{\vartheta}_{i,j}$ in association with errors.

Assuming slope homogeneity among the panel data can lead to spurious regression if the panel data is heterogeneous, according to Breitung (2005). To establish the existence of heterogeneity or homogeneity in the model, the study uses Pesaran and Yamagata (2008) approach. Equation 4 states the test statistics for the slope homogeneity.

$$\begin{aligned} \hat{\Delta} &= \sqrt{N} \left(\frac{N^{-1} \hat{S} - k}{\sqrt{2k}} \right) \\ \tilde{\Delta}adj &= \sqrt{N} \left(\frac{N^{-1} \tilde{S} - k}{\sqrt{2k}} \right) \end{aligned} \quad (4)$$

Where $\hat{\Delta}$ and $\tilde{\Delta}adj$ indicate standardized dispersion and the biased-adjusted statistics, respectively.

The existence of cross-sectional dependence among the series indicates that the second-generation panel unit root must be employed. The study employs both Im-Pesaran-Shin and CIPS unit root tests to achieve this. The CIPS test is stated in Equation 5 below.

$$CIPS(N, T) = \bar{T} = N^{-1} \sum_{i=1}^N t_i(N, T) \quad (5)$$

Where T and N are time and cross-sections

Next is to perform a cointegration test. The cointegration method used in the study is Westerlund's (2007) method, which is referred to as a second-generation panel cointegration test and can be used in situations where the variables are cross-sectional dependent. The null hypothesis of no cointegration can be rejected at either 1%, 5% or 10% if the statistic value below is greater than the critical value at any of these levels of significance. Lastly, we estimate equation 2 using PCSE and FGLS.

Descriptive Statistics

Table 1 discusses the descriptive statistics and pairwise correlation among the variables. The average values of carbon emissions (CO₂), economic complexity (ECI), economic complexity square (ECI²), gross domestic product (GDP), urban population (URP), and renewable energy (REN) are given to be 2.943, -0.106, 0.931, 5319.549, 54903828, and 29.663, respectively. The maximum (12.225) and minimum (0.140) values of CO₂ are noted in South Korea (2018) and Bangladesh (1996), respectively. South Korea in 2016 and Nigeria in 2004 have the maximum (2.169) and minimum (-2.337) values of ECI, respectively. This suggests that South Korea of all the Next 11 countries is involved in the production of more sophisticated products and emissions of carbon dioxide, while Nigeria among the Next 11 countries contributes less to the production of advanced goods. Bangladesh is seen to be the country with the least emission of carbon dioxide. Since the average values of the variables fall within the minimum and maximum values, the results demonstrate that the variables are consistent. The standard deviation values show that the variables do not depart from their mean values. Also, Table 2 shows that while carbon emissions have a negative correlation with renewable energy and urban population, they have a positive correlation with economic complexity, GDP per capita, and economic complexity square. There is a significant correlation between all the variables and carbon emissions, except the urban population. Furthermore, since none of the correlation coefficients for the explanatory variables are higher than 0.80, there is no proof of multicollinearity among them.

Table 1: Descriptive statistics and pairwise correlation analysis (Source: Author's computations)

	Descriptive statistics					
Statistics	CO ₂	ECI	ECI ²	GDP	URP	REN
Mean	2.943	-0.106	0.931	5319.549	54903828	29.663
Maximum	12.225	2.169	5.460	31640.21	1.51E+08	88.680
Minimum	0.140	-2.337	9.88E-07	559.690	16349444	0.440
Std. Dev.	3.040	0.961	1.231	6363.750	26590364	25.337
Observations	275	275	275	275	275	275
	Pairwise Correlation					
	CO ₂	ECI	ECI ²	LGDP	LURP	REN
CO ₂	1.000					
ECI	0.632***	1.000				
ECI ²	0.330***	-0.065	1.000			
LGDP	0.871***	0.752***	0.299***	1.000		
LURP	-0.0163	0.0673	0.0822	0.178***	1.000	
REN	-0.692***	-0.696***	0.294***	-0.701***	0.014	1.000

Note: *** $p < 0.01$, ** $p < 0.05$

Results and Discussion

Cross-Sectional Dependence, Panel Unit Root, Cointegration, and Homogeneity Tests

The Pesaran CSD test, as described in Pesaran (2004), is used to determine whether there is cross-sectional dependence in the series to be estimated. The null hypothesis that there is no cross-sectional dependence is rejected for every variable at the 1% level of significance, as seen in Table 2. This implies that there is evidence of cross-sectional dependence in the series, meaning that a shock in one of the Next 11 countries can be transferred to another. To account for cross-sectional dependence, the study uses both the Im-Pesaran-Shin (IPS) test and the Pesaran (2007) second-generation unit root test (CIPS). With the exception of economic complexity, all of the variables' estimates from the two tests show that they are I(1) and that they are stationary at first indifference.

A long-run association between the relevant variables is evident as the Westerlund (2007) cointegration finding rejects the null hypothesis that there is no cointegration among the variables. As the study rejects the null hypothesis of slope heterogeneity, the slope homogeneity test according to Pesaran and Yamagata (2008) in Table 2 shows the presence of slope heterogeneity in the panel analysis. These

results suggest that the study has to use an analysis approach that takes into consideration the slope heterogeneity and cross-sectional dependence among the variables.

Table 2: Pesaran CSD, panel unit root, cointegration, homogeneity test (Source: Author's computations)

Variable	CSD-test	Unit Root Test			
		IPS Unit Root Test		Pesaran (2007) CIPS	
		Level	1 st Diff.	Level	1 st Diff.
CO ₂	16.00***	2.902	-8.800***	-0.783	-3.783***
ECI	14.54***	-0.3470	-10.337***	-2.945***	-5.415***
ECI ²	-2.42**	-1.136	-10.864***	-2.493***	-5.302***
LGDP	34.49***	2.737	-3.579***	-2.143	-2.989***
LURP	36.92***	1.540	-3.091***	-2.309	-2.381**
REN	12.62***	5.891	-7.378***	-1.631	-4.379***
Westerlund (2007) Cointegration Test					
	Without E _c KC	With E _c KC			
Variance ratio	-1.841**	-1.521*			
Pesaran and Yamagata (2008) Slope Homogeneity Test					
	Without E _c KC	With E _c KC			
Statistic	18.344***	15.207***			

Note: ***p<0.01, **p<0.05, *p<0.10; N/A: Not Applicable

Economic Complexity and Carbon Emissions

The study uses feasible generalised least squares (FGLS) regression for robustness checks and the corrected panel standard error estimation (PCSE) technique to investigate how economic complexity impacts carbon emissions in the Next 11 nations (see Table 3). The results are discussed basically on the variables of interest. The direction of the findings produced by both methods is similar, indicating that the FGLS and PCSE estimations are consistent. In the absence of the non-linear term of ECI, economic complexity has an insignificant positive impact on carbon emissions; nevertheless, when the economic complexity-Kuznets curve (E_cKC) relationship is tested, its impact on carbon emissions is both positive and significant. Therefore, the Next 11 countries' increased production of high-tech items would result in higher carbon dioxide emissions. The result is comparable to that of Laverde-Rojas et al. (2021), who found that increasing country's production sophistication can raise carbon dioxide emissions, which reduces the quality of the environment. Therefore, countries with high ECI are probably responsible for some of the environmental damage caused by their carbon dioxide emissions. The result implies that as the Next 11 countries progress towards producing sophisticated goods, there will be a rise in carbon dioxide emissions. More complex countries degrade the environment excessively, whereas lower-complexity countries often generate agricultural products and cause little environmental damage (Satrovic & Adedoyin, 2022). The results of Abdi (2023), Can and Gozgor (2017), Dogan et al. (2019); Kılıç et al. (2023), Kirikkaleli et al. (2023), Neagu and Teodoru (2019), Saqib et al. (2023), which suggested that economic complexity causes a lower level of carbon emissions in the selected countries, are not consistent with the finding that economic complexity has a positive relationship with carbon emissions. This indicates that countries with high ECI tend to invest significantly more in cleaner technologies due to their concern about high consumption of non-renewable energy. The ECI for the Next 11 countries reveals a positive trend, indicating a progressive shift towards the production of more advanced items (see Fig.1). Therefore, most countries belonging to the Next 11 countries are not using clean production technology. Economic complexity still significantly increases carbon emissions, even though the Next 11 countries are actively conserving energy and safeguarding the environment, as stated by the majority of research, including Paramati et al. (2017), Shahbaz et al. (2016), and Yildirim et al. (2014).

Both the linear and non-linear term of ECI significantly increases carbon emissions, regardless of the development level in the Next 11 countries, as captured by the economic complexity-Kuznets curve (E_cKC). The economic complexity-Kuznets curve (E_cKC) in the Next 11 countries is refuted in this study. Table 3 (columns 4, 8) shows a linear relationship between economic complexity and carbon

emissions that increases monotonically. Specifically, $\lambda_1 > 0$ and $\lambda_2 > 0$, meaning that the study is consistent with the “*pollution haven theory*” and supports a positive monotonic economic complexity-emissions link. This outcome is similar to the study of Boleti et al. (2021) but the study used GDP and not ECI to test the EKC hypothesis. The implication is that the study does not support either the U-shaped or the inverted U-shaped link between economic complexity and carbon emissions, hence the turning point for carbon emissions would not be applicable. The economic complexity-Kuznets hypothesis (E_cKC) is rejected in the Next 11 countries. This finding does not align with the studies of Balsalobre-Lorente et al. (2023) and Neagu (2019) who accepted the E_cKC hypothesis in BRICS countries. The findings disagree with Yu et al. (2022) who validated the U-shaped association between economic growth and environmental degradation. This could be explained by the difference in the choice of variables used in testing the EKC hypothesis and also, the difference in the estimating technique employed.

Growth in the productive capacity of the Next 11 countries is predicted to increase carbon emissions in the countries (Adeleye et al., 2023; Hamid et al., 2022; Kirikkaleli et al., 2023; Salahuddin et al., 2018), which is unsurprising, given that the majority of the Next 11 countries producing goods and services will send carbon dioxide into the atmosphere. This outcome is inconsistent with Yu et al. (2022), which could be attributed to differences in research methodologies. Surprisingly, the urban population has a negative effect on carbon emissions. The negative impact of urban population on carbon emissions is consistent with Azizrahman and Hasyimi (2019) in high-income countries and lower-middle countries in the long run and Kazemzadeh et al. (2022), while it contradicts Adeleye et al. (2022), Lin et al. (2017), and Yang et al. (2018), who opined that urbanization or population growth leads to higher carbon emissions. Renewable energy has a negative effect on carbon emissions, which aligns with Abdi (2023), Adeleye et al. (2023), Balsalobre-Lorente et al. (2023), Hsu (2021), Murshed et al. (2022a), Nguyen and Kakinaka (2019), Salahuddin et al. (2018), Saqib et al. (2023), and Szetela et al. (2022). Since most renewable energy sources do not emit carbon dioxide or pollute the air when generating heat or electricity, this favourable effect of renewable energy on carbon emissions is to be expected.

Table 3: PCSE and FGLS results (Dependent Variable: CO₂) (Source: Author’s computations)

Variable	PCSE (Main Analysis)				FGLS (Robustness)			
	Without E_cKC		With E_cKC		Without E_cKC		With E_cKC	
	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value	Coeff.	p-value
ECI	0.063 (0.071)	0.375	0.183** (0.086)	0.033	0.062 (0.070)	0.377	0.273*** (0.084)	0.001
ECI ²	N/A	N/A	0.144*** (0.039)	0.000	N/A	N/A	0.177*** (0.039)	0.000
LGDP	6.017*** (0.590)	0.000	5.765*** (0.528)	0.000	4.415*** (0.590)	0.000	5.302*** (0.426)	0.000
LURP	-3.061*** (0.744)	0.000	-3.058*** (0.517)	0.000	-2.201*** (0.728)	0.003	-2.781*** (0.442)	0.000
REN	-0.020*** (0.007)	0.003	-0.018*** (0.005)	0.000	-0.019*** (0.007)	0.007	-0.014*** (0.004)	0.001
Constant	6.227 (5.215)	0.232	6.716** (3.006)	0.025	4.666 (5.097)	0.360	5.871** (2.669)	0.028
Turning point	N/A		N/A		N/A		N/A	
Observations	275		275		275		275	
Countries	11		11		11		11	
R-squared	0.440		0.584		N/A		N/A	
Wald statistic	210.91***	0.000	431.50		116.13***	0.000	477.04***	0.000

Note: *** $p < 0.01$, ** $p < 0.05$; standard errors are reported in parenthesis. N/A: Not Applicable

Conclusion

Environmental sustainability is among sustainable development goals (SDGs) to be achieved by 2030. Meanwhile, one of the ways to achieve this is to curtail the release of carbon dioxide in an economy. In light of this, the study examines the effect of economic complexity on carbon dioxide emissions in the Next 11 countries (Bangladesh, Egypt, Indonesia, Iran, Mexico, Nigeria, Pakistan, Philippines, South Korea, Turkey, and Vietnam) with the view to validate or refute the economic complexity-Kuznets curve (E_cKC) between 1995 and 2019. The study focuses specifically on E_cKC because the selected countries are moving towards the production of advanced goods which can add to environmental degradation. The study employs two econometric techniques: correlated panel standard error (PCSE) and feasible generalized least squares (FGLS) estimating techniques. The estimates from the FGLS approach are consistent with that of the PCSE approach. The results show that the next 11 countries' carbon dioxide emissions are found to rise with economic complexity. Additionally, according to E_cKC hypothesis, the study refutes the hypothesis and supports a positive monotonic linear relationship between economic complexity and carbon emissions, which also means the “*pollution haven hypothesis*”. The inference drawn from these results is that carbon emissions will rise as the Next 11 countries shift to producing sophisticated goods. Stated differently, environmental challenges will start to rise as the Next 11 countries become less energy-efficient and more industry-intensive to encourage economic complexity. This is because the production of advanced items will require more energy, which will increase energy consumption and, if proper actions are not taken, can lead to an increase in carbon dioxide emissions.

A further rationale for the positive relationship between economic complexity and carbon emissions may be from the substantial number of industries present in the countries, especially in those with positive ECI like South Korea, Mexico, the Philippines, and Turkey. Based on its findings, the study contributes significantly to the existing knowledge by demonstrating that environmental degradation in the Next 11 countries will result from an increase in the production of sophisticated commodities (economic complexity). It is claimed that the health of the nation's citizens is negatively impacted by environmental deterioration caused by carbon dioxide emissions, which may have a knock-on effect on the economy as a whole. Also, the study disproves the Kuznets theory of economic complexity in the Next 11 countries but supports the “*pollution haven hypothesis*”, which holds that there is a positive monotonic linear link between economic complexity and carbon emissions.

Since the Next 11 countries are already known to be progressively achieving greater economic complexity, as shown in Figure 1, steps should be taken to make sure that producing sophisticated commodities does not result in higher carbon emissions. This can be achieved in the selected countries by engaging in the use of cleaner energy and technologies that do not pollute the air. As economies get more complex, there is a need to employ cleaner energy and better technology, which will help meet SDG 7 in reducing carbon dioxide emissions. Also, using renewable energy instead of non-renewable energy in the production of (complex) goods and services. This is considered significant since renewable energy sources, such as wind, hydro, and solar, lower carbon emissions linked to burning fuel during production processes. Renewable energy provides cleaner alternatives to fossil fuels and helps in promoting energy efficiency. Lastly, decarbonizing other sectors like the transportation sector would go a long way in lowering carbon emissions. This can be achieved by switching fossil fuels with biofuels in the sector. This study is not without limitations. The present study focuses on the causal effect of increasing production leading to environmental pollution. It might be more realistic to account for other factors that can influence this relationship. These include global trends of implementations of SDGs, country contributions to the environmental fund, implementation of taxonomies beyond EU countries and challenges of reaching net zero on country levels. Also, the same subject matter of this study can be examined in different regions of the world or other emerging economies like MINTS and BRICS countries.

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