Environmental Degradation, Energy Consumption and Sustainable Development: Accounting for the role of Economic Complexities with evidence from World Bank Income Clusters

Abstract

The anthropogenic consequences of renewable and non-renewable energy consumption, economic growth and air transport have been assessed enormously in the literature. However, given the complexities in many economies of the world today, it is important to reassess the ecological concerns of these factors in light of the Environmental Kuznets Curve. Therefore, this current study investigates the global assessment using data from World Bank Development database from 1995 to 2016. Evidence from the method employed, sys-GMM, revealed that the economic complexities index increases the carbon emission in low-income groups while it significantly decreases the carbon emission for upper-middle and high-income groups. For the combined group, the EKC hypothesis holds and ECI significantly hampers carbon emissions. For the other variables, it is worthy of note that: (1) economic growth contributes to the high carbon contents across the income group especially for low-income, upper-middle-income and high-income group; (2) the effects of air transport on carbon emission is positive for lower-middle-income and high-income group and negative for the upper-middle-income group; (3) the use of coal rents and energy use leads to high release of carbon contents across all the income groups; and (4) a significant increase in the utilization of energy leads to increase in carbon contents except for lower-income group it leads to a decrease. From this empirical assessment, vital energy policy directions are suggested.

Keywords: Emissions; Energy Use; Coal Rents; Economic Complexity Index; Economic Growth; Income Clusters; Environmental Degradation; Air transportation

1. Introduction

The impact of human activities on the environment includes changes that occur in the biophysical environments, economic systems, diversity in the biological system caused by global warming, and environmental degradation etc. These changes largely resulted from one or two economic activities such as implications of tourism or international travel, economic complexities, and energy consumption. Talking of international travel or tourist activities boost the importance of cultural activities as well as the economy. It creates development leverage for developed and developing countries, for instance, Japan and the United States have been said to pay little attention to investing in tourist attractions, but its development strategies now include tourism as both countries have recently implemented tourism attraction policies, such as relaxed visa regulations, to encourage inbound foreign travel, creating jobs opportunities and boost the slow economy. In 2013, Japan was able to host about 10 million foreign visitors and hoped to double the numbers by Olympics in Tokyo by 2020, but for the covid-19 pandemic and looked to have increased foreign visitors to 30 million by 2030. Also, the United Nations World Tourism Organization (UNWTO) forecast that tourist arrivals are expected to grow by 3.3% per year from 2010-2030 and reach 1.8 billion by 2030. Increasing tourist travels by relaxing travel and foreign regulations not only improves the economy and developmental goals of the country but may also lead to increase in carbon dioxide emissions, contributing to 8% of global greenhouse gas emissions resulting from the provision of accommodation, transportation, increased food production, and recreational activities (Paramati et al., 2017; Sharif et al., 2019; Rafindadi,2019; and Adedoyin, 2020b).

Also, economic complexities measured by economic complexities index (ECI) contribute to the increase in environmental degradation or emission. ECI holistically measure the extent of productive capacities of large financial framework situated usually in regions, cities and even countries. It seeks to provide explanations to capabilities of population expansion expressed in form of economic activities in cities, countries or a particular region. It also determines their productivity considering activities that come with economic expansion and complexities such as tourism, urbanization, population etc. However, ECI has its economic deficiency, it may increase implies an increase in carbon emissions (Shahzad et al., 2021), although most literature reviewed attest that ECI plays an important role in reducing environmental emission (Can and Gozgor, 2017)

Moreover, energy consumption implies that all energy used to carry out the manufacturing process, commercial purposes, and residential purposes etc. But the implication of more usage of energy may include a rise in carbon dioxide emissions. This result in a causal relationship between the consumption of energy and the emissions of carbon, particularly non-sustainable/renewable energy. Hence, minimizing the emissions without hindering the economic growth required to increase energy supply and energy efficiency while improving energy conservation policies to reduce energy wastage (Pao & Tsai, 2010; Dogan & Ozturk, 2017; Ozturk, 2017).

Furthermore, the figures (1-4) below buttress more significant impacts on the aforementioned explanation. For example, Figure 1 shows the relationship between tourist arrivals and emissions. It was evident that, even though there was more interaction between energy use and carbon emissions, there is between international travel/tourism and carbon emissions. This is because from 2000-2018, energy use increases, as well as carbon emissions and energy use, dropped in 2015 as carbon emissions continued to increase until 2017 when carbon emissions experienced a slight drop in value for Kuwait. International travel on the other hand continued to increase continuously from 2009-2018 irrespective of whether energy use increased or decreased.

Also, Figure 2 identifies the interrelationship that exists between energy consumption and carbon emissions from 2000 – 2015. Carbon emissions for countries increase as energy consumed by countries increases. For instance, energy consumption in Kuwait was 11134.24kg and carbon emissions were 87303.94kt while energy consumption in India as 544.6266kg and carbon emissions was 1738646kt. In 2000 energy use was 1636.7 and carbon emissions was 24935.6 and by 2013 energy use increase to 1896.4 and carbon emissions also increased to 35841.258kt.

Figure 3 indicates the ECI and environmental degradation measured by carbon emissions. It shows the interrelationship between economic complexities and environmental degradation which means that countries with high economic complexities index are accompanied by high carbon emissions for those countries or instance china had its ECI at 0.6649 and carbon emissions at 7557790kt. Although world carbon emissions continued to increase as the economic complexities index fluctuates. Furthermore, Figure 4 shows the relationship between ECI, tourism and emissions of the global countries from 2000 – 2014. It shows that as tourism increases emissions increases simultaneously while energy consumption seems to fluctuate as both ECI and carbon emissions increase. Except for 2015 when the three indicators experienced a slight drop and rise back in 2016.

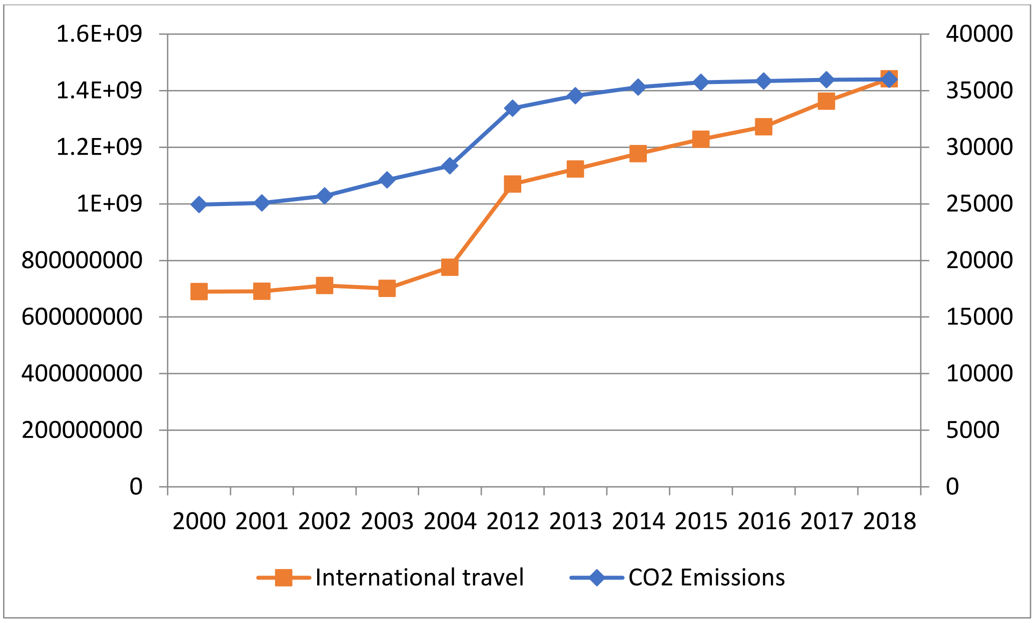


Figure 1. World Tourism and Carbon emissions

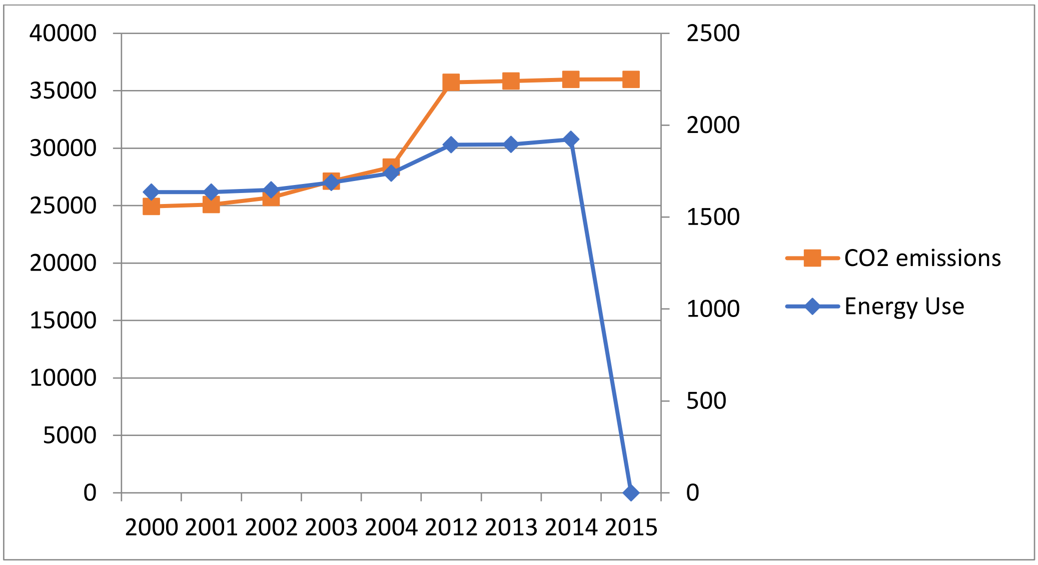


Figure 2 World energy consumption and emissions

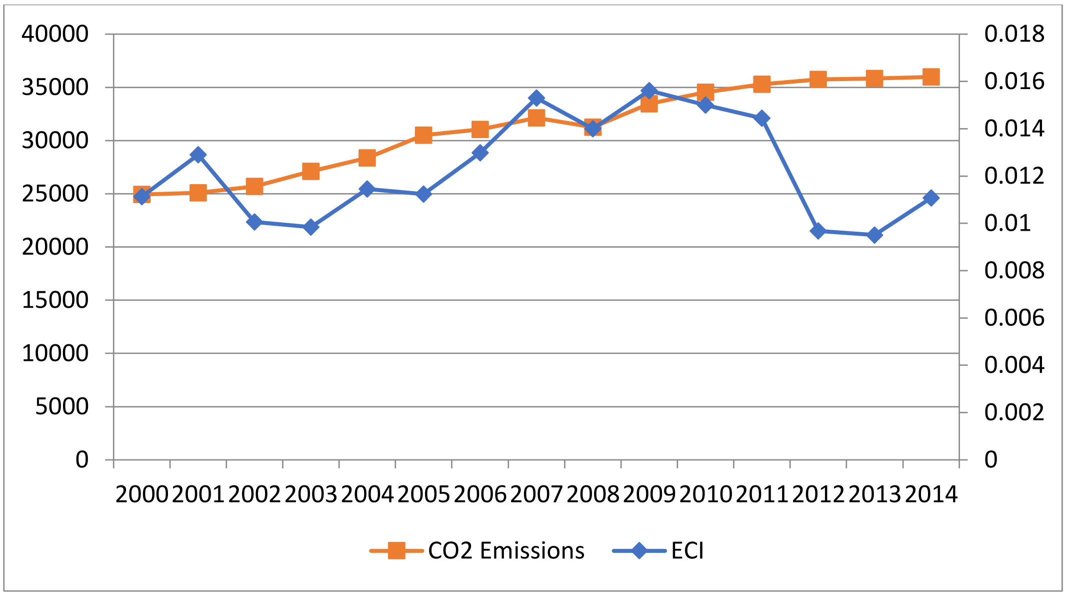


Figure 3. World ECI and environmental degradation ECI and Emissions

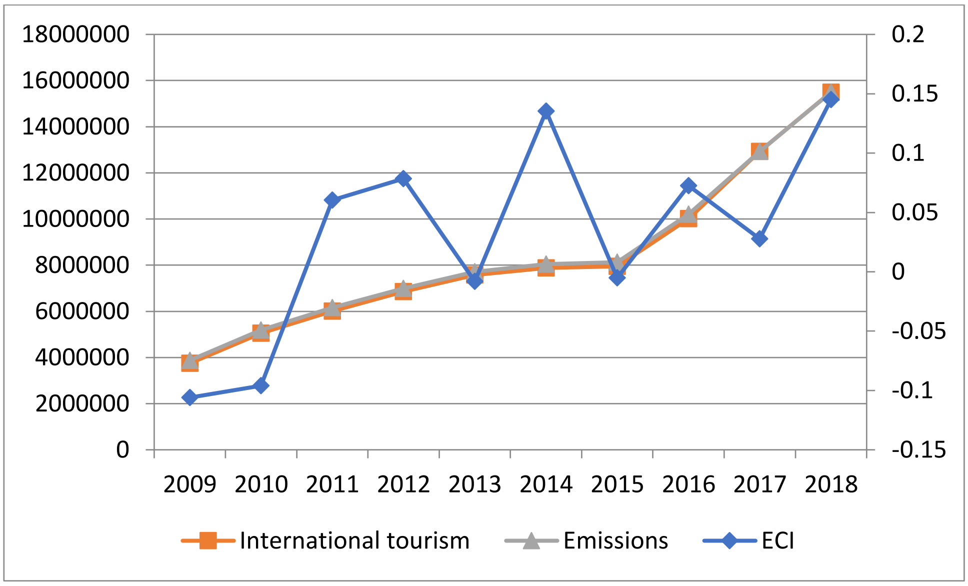


Figure 4. ECI, Tourism and emissions of countries of the world from 2009-2018

The environmental Kuznets curve proves that as an economy develops, environmental degradation continues to rise until a certain level of economic development when environmental degradation begins to decline. The environmental Kuznets hypotheses and economic complexity relationship with environment show the need for economic advancement and complexity. Economic advancement gives countries the capacity to invest in renewable energy and financial development which contributes towards mitigating environmental degradation, (Al-Mulali, Ozturk, et al., 2016).

This study considers economic complexities index, international travel or tourism and energy consumption impacts on the environment i.e., how and whether or not do they contribute to environmental degradation.

2. Literature Review

2.1 Economic Complexity Index and Environment Nexus

Economic complexities index is a proportion of the productive abilities of enormous economic systems, usually urban cities, regions and countries. Presenting the ranking of economic complexity of countries, the observatory of economic complexity in 2016, shows that Japan has 2.43 ECI, Switzerland 2.17, South Korea 2.11, Singapore 1.85, Austria, 1.81 and down the rankings is less developed countries like democratic republic of Congo and Nigeria with -1.80 and -1.90 index respectively. This shows that fast-developing and developed countries have higher economic complexity index compared to less developing countries and this implies that the higher the ECI, the higher the economic development and or advancement and vice-versa. However, these economic complexities may be beneficial to and an indication of economic development, but it may as well be an indicator of environmental congestion and pollution since economic activities make up the economic complexity index.

Meanwhile, investigating whether or not economic complexity contributes to the environmental depreciation, Doğan et al., (2019) conducted analysis for different stages of economic development and it was discovered that economic complexity index has a significant impact on the ecosystem and this impact vary for countries in different stages of development. Economic complexity increases the ecological debasement in lower and higher middle-income countries considering the economic activities that come with economic complexity. Therefore, it is important for low and middle-income regions to make changes to their current industrial and production guidelines to foster economic growth and development while ensuring environmental protection and sustainability.

Similarly, Can and Gozgor, (2017) seek to find the impact of economic complexity on carbon emissions drawing evidence from France. Apart from confirming the validity of the environmental Kuznets curve, it was also discovered that increasing economic complexity index suppresses the emissions of carbon dioxide. This implies that there is a need for drastic environmental policy measures to drive the focus of reducing the level of carbon dioxide emissions and environmental degradation. Taking a step ahead, Shahzad et al., (2021) investigated the relationship between economic complexity, energy consumption and ecological footprints.

Adopting fresh insights from quantile methods, they found that economic complexity and fossil fuel energy consumption contributes greatly to enhancing ecological footprints confirming a causal relationship between economic complexity, energy consumption and ecological footprints. This is because the economic complexity comes with increased economic activities and fossil fuel energy consumption is associated with high carbon dioxide emission.

Thus, the need for a shift from the consumption of fossil fuel energies which are known to be non-renewable and advancement towards renewable energy consumption to ensure economic advancement and environmental quality. Furthermore, González et al., (2019) adopted a multi-criteria investigation of economic complexity transition for developing economies with a focus on finding the sectors of the economy that contributes more to economic complexity. It was discovered that economic transition to a more complex economy involves the need to boost the wood industry which will enable the attraction of landowners and incentivize improved management service for forests to minimize deforestation rates which results from a high demand for wood as energy sources.

2.2 Energy Use, International Travel and the Environment

Economic development and economic activities require energy consumption at one stage of development or the other. This means that energy consumption is a necessary aspect of economic development which comes along with emissions of greenhouse gases which may be detrimental to environmental quality. In their findings, Al-Mulali, Solarin, et al., (2016) confirmed that consumption of fossil fuel energy, gross domestic product, urbanization and trade openness (ECI) contributes to carbon dioxide emissions and thus environmental degradation in the long run. However, only in the long run does financial degradation contribute to the reduction of air pollution.

In their investigation, Pao and Tsai, (2010) examined the interaction between the emissions of carbon, energy consumption and economic growth. A two-way causal link was found between energy consumption and carbon emissions and the same relationship between energy consumption and output. To however minimize carbon emissions and ensure economic growth is not adversely affected to ensure increased energy supply investments and energy efficiency thus moving closer to energy conservation policies and reduce avoidable energy wastage. Also, Zhang et al., (2019) investigated the energy-related carbon dioxide emissions peaking target and pathways and it was discovered that carbon emissions from industrial production make up over 80% of the total carbon emissions and emissions from six energy-consuming industries account for about 40% of the total emission of carbon dioxide in the city of China. Additionally, economic growth was found to contribute significantly to the growth of carbon dioxide emissions with the structure of the industry and population growth having little contributions to carbon dioxide emissions.

Considering the role of energy use on the emissions of carbon and environmental degradation, there are a lot of concerns about the source of energy use that contributes to carbon emissions and which does not. Dogan & Seker, (2016) investigated the role of sustainable and non-sustainable energy consumption in determining carbon dioxide emissions. They discovered that non-sustainable energy consumption contributes to increasing carbon dioxide emissions while the emission reduction goals can be achieved with increased trade and renewable energy consumption. The direction of causality between renewable energy and carbon emissions is also bidirectional with a one-way causality from carbon emissions and non-renewable energy and trade openness and carbon emissions. The implications of non-renewable energy consumption to the environment are detrimental thus the need to encourage renewable energy consumption to foster economic growth and environmental quality at the same time.

Similarly, Hanif et al., (2019) investigated the emissions of carbon dioxide across the spectrum of renewable and non-renewable energy consumption and found evidence that renewable energy consumption contributes to the mitigation of carbon dioxide emissions while the consumption of non-sustainable energy contributes to the rise in carbon emission. As a push for increased energy consumption, depletion of natural resources and population increase are contributors to carbon emissions. A movement from non-renewable to sustainable and renewable energy sources is unavoidable when nations desire to mitigate carbon emissions and promote carbon-free economic growth. It is imperative to encourage regional cooperation on the carbon reduction goal to reduce carbon emissions and for increasing investments in clean energy projects.

On another note, investigating whether renewable energy-matter in the emissions reduction goals, Adams and Nsiah, (2019) adopted the fully modified ordinary least square and GMM techniques and found that renewable and non-renewable energy contribute immensely to carbon dioxide emissions in the short run but only non-renewable energy consumption contributes to carbon emissions in the long run. Also, economic growth contributes to environmental degradation while urbanization may impact negatively carbon emissions. Importantly, Inglesi-Lotz & Dogan, (2018) confirmed that increased renewable energy consumption helps reduce carbon emissions while the reverse is the case for non-renewable energy consumption. In their investigation of the interaction between energy consumption, economic expansion and CO2 emissions considering the role of economic policy uncertainties, Adedoyin & Zakari, (2020a) found economic policy uncertainty to yield a positive effect on climate change in the short run but prolonged dependence on economic policy uncertainty creates an unhealthy environment.

Investigating players that serve as an influence on the tourism industry's carbon emissions, Tang et al., (2017) showed that increase in the scale of tourists and tourism output contributes immensely to the growth of tourism-related carbon emissions. Decomposition of tourism greenhouse gas emissions, Sun, (2016) revealed the dynamics of the interaction between tourism, economic growth, technological efficiency and carbon emissions. It was discovered that technological advancement does not meet the pace of tourism emissions. There is also a need for governmental intervention because enhancing energy efficiency among tourism-characteristic industries particularly air and land transportation lags compared to other sectors. This shows that not only does a country like Taiwan experiences increasing carbon emissions in the tourism industry but is also accompanied by deteriorating tourism-related carbon efficiency. On a similar note, Paramati et al., (2017) seek to discover whether or not does tourism degrade the environmental quality and it was discovered that tourism contributes to improving the economic growth as well as contributing to increases in carbon dioxide emissions. This implies that tourism is important for economic growth thus the need for policies to manage the emissions effects of tourism to ensure economic growth and environmental quality at the same time.

However, (Khan et al., 2019) investigated the link that exists between financial development, international travel, renewable energy and greenhouse gas emissions on a continent based analysis. Findings showed that there is unidirectional causality from financial development to greenhouse gases for Asia and America, from trade openness to carbon emissions for Asia, Europe and America, tourism to carbon emissions in Asia, Europe and America. Furthermore, there is a one-way causal relationship between tourism to renewable energy in Europe, between financial development and trade and between tourism and renewable energy in America. The differences in the level of causality for each region shows the need for adjustment of governmental policies to suit region peculiarity. it is important to fix the compulsory focus of sustainable energy by putting in place a separate agency for renewable energy. Governments should ensure efficient use of energy resources as well as provide financial support to the eco-friendly projects at subsidized and low interests. It is important to also ensure the promotion of environmentally friendly tourism activities and processes by ensuring the use of eco-friendly transportation methods as well as increasing the area undercover and promote environmentally friendly products by adopting the use of print, electronic and social media. The drive for environmental sustainability can go as far as including the relevance of clean ecosystem in the educational syllabus.

This study considers economic complexities index, international travel or tourism and energy consumption impacts on the environment i.e., how and whether or not do they contribute to environmental degradation. The consideration of these indicators is to identify how they contribute to emissions and how to maintain their economic relevance while maintaining economic growth. To the best of our knowledge from the literature review, no paper has considered the anthropogenic effect of ECI, International travel and energy use at the same time for the four World Bank income class. This study provides a clear interacting between these variables.

3. Data and Methods

3.1 Data and Variables

This paper uses panel data covering 119 countries from 1995 to 2016 to study the environmental consequences of economic complexities, air travel and energy use. The system generated method of moment (system GMM) model is used to empirically achieve the objective.

Table 1. Description of variables

Variables	Acronym	Data source
Carbon dioxide emission per capita	CO2PC	World Bank Development Indicator
Real GDP per capita growth	RGDP	World Bank Development Indicator
Squared Real GDP per capita growth	RGDP2	Author calculation
Energy use	EU	World Bank Development Indicator
Air transport	AIR	World Bank Development Indicator
Economic complexities Index	ECI	ATLAS of economic complexity index
Coal rents	COR	World Bank Development Indicator

3.2 Model and Method

The model constructed below tends to measure the influence of the indicator variables on carbon emission. The environmental Kuznets curve has been significantly studied in the literature and this study makes a theoretical contribution by including the following:

$$CO_2 = f\ (RGDP, RGDP2, AIR, ECI, EU, COR) \qquad [1]$$

To achieve the aim of equation 1; the analysis, after presenting the summary statistics, pairwise correlation, and visualizing bin scatter plots of the variables of interest, was estimated using two different models. The first one being a static model is the pooled OLS, Fixed effect (FE) model, Random effect (RE) model. The second one being dynamic ARDL model (system GMM) assess the serial correlation by taking the lag of dependent variables and control for heteroscedasticity, and endogeneity and measurement error of the dependent variables (Arellano and Bond, 1991). Pooled OLS is a linear regression without fixed or random-effect model properties, the model estimates intercept and slopes of regressors without taking into account the individual (a country in this case) and/or time effects. Its basic scheme is to test the effects of air transport, energy use, ECI, coal rents, and economic growth on carbon emission per capita. The model takes the form:

$$\log CO_2PC_{it} = \beta_{0i} + \beta_{1i}\log RGDP + \beta_{2i}\log RDGP2 + \beta_{3i}\log AIR + \beta_{4i}ECI + \beta_{5i}\log EU + \beta_{6i}\log COR + \varepsilon_{i,t} \quad [2]$$

However, when country (income group in this case) effect is taken into account, then there will be the introduction of dummy variables into the regression, hence the pooled OLS becomes least squared dummy variables (LSDV). Thus, the equation becomes:

$$\log CO_2PC_{it} = \beta_{0i} + \beta_{1i}\log RGDP + \beta_{2i}\log RDGP2 + \beta_{3i}\log AIR + \beta_{4i}ECI + \beta_{5i}\log EU + \beta_{6i}\log COR + \gamma_i(dummy)_{n-1} + \varepsilon_{i,t} \quad [3]$$

Where $\log CO_2PC$ is the log transformation of carbon emission per capita, logRGDP is the log of economic growth per capita, logRDP2 is the log of squared of economic growth per capita, log of air transport, ECI is the economic complexities index, logEU is the log of energy use, logCOR is the log of coal rent, γ_i are the coefficient of n – 1 dummy entities included in the model, and $\varepsilon_{i,t}$ is the error component for *i,t* = 1, 2, …… Equation 2 and 3 are, respectively, used to evaluate the four division of income group and combine group in the analysis stage. Fixed effect model, without dummy variables, only examined the entity differences in the intercept. It does not take into account the error component across the entity (country). It was designed to study the actual courses of changes within an individual or entity. The structured model then follows:

$$\log CO_2PC_{it} = \beta_{0i} + \beta_{1i}\log RGDP + \beta_{2i}\log RDGP2 + \beta_{3i}\log AIR + \beta_{4i}ECI + \beta_{5i}\log EU + \beta_{6i}\log COR + u_{i,t} \quad [4]$$

Where all variables have their usual meaning and $u_{i,t}$ is the error term.

The random-effects model examines how entity and/or time influences the error variances, as such the structured model include both the between error (individual error) and within entity error (time component error).

$$\log CO_2PC_{it} = \beta_{0i} + \beta_{1i}\log RGDP + \beta_{2i}\log RDGP2 + \beta_{3i}\log AIR + \beta_{4i}ECI + \beta_{5i}\log EU + \beta_{6i}\log COR + u_{i,t} + \varepsilon_{i,t} \quad [5]$$

Where all variables have their usual meaning $u_{i,t}$ is the individual error term and $\varepsilon_{i,t}$ is the time component error term.

However, the static model does not control for the presence of slope heterogeneity endogeneity, and serial correlation (Pugh and Geoffrey, 2014). System GMM allows for the inclusion of endogenous structure into the model through instrumental variables. This endogeneity is defined as the existence of a correlation between the dependent variable and the error term, which is related to the causal relationship between the variables explaining the model (Mileva, 2007; Wooldridge 2013). In economic terms, endogeneity can be interpreted as the effect of the past on the present, both on the model (dependent variable) and on the independent variables, or as the causality relationship between regressors and explained variable along the time. The dynamic model is useful when the dependent variable depends on its past realizations:

$$\log CO_2PC_{it} = \alpha_{1i}\log CO_2PC_{it-1} + \alpha_{2i}\log CO_2PC_{it-2} + \beta_{0i} + \beta_{1i}\log RGDP + \beta_{2i}\log RDGP2 + \beta_{3i}\log AIR + \beta_{4i} ECI + \beta_{5i}\log EU + \beta_{6i}\log COR + u_{i,t} + \varepsilon_{i,t}$$

Where: $\log CO_2PC_{it-1}$ *and* $\log CO_2PC_{it-2}$ is the lag of the dependent variable, and α is the coefficient of the lag. All other parameters have their usual meaning.

4. Results and Discussions

This section presents the summary statistics, correlation, and bin scatter plots of the studied variables. Then, the estimation across different income group according to the World bank. Finally, static models and system GMM techniques were used to estimate the influence of the predictors' variables on carbon exhaust for all combined income group countries. Table 2 expose the statistics of the variables of interest and log of variables of interest. With an emphasis on the original variables, the average of coal rent (%GDP) is 0.19 with a standard deviation of 0.89 explaining very small disparity among the observations and its mean. Real GDP per capita has an average of $14194.36 within the maximum and minimum value of $91565.73 and $183.55 with a standard deviation of $17936.98 explaining very low measures because of high variance among the observations. On average, energy use (%GDP) has a mean of $149.62; the standard deviation of 112.21 and range of 865.16 and 39.099. Furthermore, the average CO_2 emission per capita is $5.83 within the $70.04 and $0.162 with a deviation of $7.31 which means that there is little dispersion among its observation. For air transport and economic complexities as a percentage of GDP. Their mean is $1.93 billion and $0.11 billion respectively. The value of their standard deviation denotes that air transport (with a value of $7.04 billion) has higher dispersion that economic complexities with a standard deviation of $0.977.

However, after using logarithmic transformation on the variables, it was observed that the average value and most importantly the standard deviation of the variables has reduced drastically. For instance, the standard deviation of coal rent (%GDP) is now $2.95 as compared to $14194.36

when using the original data. This is an indication that the dispersion among the coal rents observation is very low which is a good measured. Also, the mean value of log CO_2 emission is 1.03; the minimum is -4.11 and maximum is 4.24, and the standard deviation is 1.40. For real GDP per capita, it has an average value of $8.70 with a standard deviation of $1.41, it also has a minimum and maximum value of $5.21 and $11.42. Moreover, the square of real GDP per capita has a mean value pf $77.77; maximum of 130.52; minimum of 27.17; and deviation of 24.45. Furthermore, energy use has an average value of 4.83 with a standard deviation of 0.53 which denotes the very low level of disparity among the observation. The air transport mean value is 14.83; standard deviation is 2.02 (a good measure of variations); minimum and maximum value of 6.47 and 20.56 respectively.

Table 2. Summary Statistics

Variable	Obs.	Mean	Std. Dev.	Min	Max
Variables at level					
COR	2,613	0.1917356	0.8901836	0	25.32737
RGDP	2,609	14194.36	17936.98	183.5479	91565.73
EU	2,399	149.6214	112.2175	39.09975	865.1604
CO2PC	2,603	5.839369	7.31486	0.0162798	70.04223
AIR	2,433	1.93E+07	7.04E+07	0	8.24E+08
ECI	2,598	0.1196581	0.977664	-2.7911	2.8951
Variables at log					
LCO2PC	2,603	1.036031	1.400802	-4.117833	4.249098
LRGDP	2,609	8.704984	1.412475	5.212476	11.42481
LCOR	1,238	-3.45018	2.954669	-14.84412	3.231886
LEU	2,399	4.835115	0.5393647	3.666116	6.762915
LAIR	2,425	14.83797	2.027949	6.467854	20.52973
LRGDP2	2,609	77.77107	24.54518	27.1699	130.5263

Correlation matrix

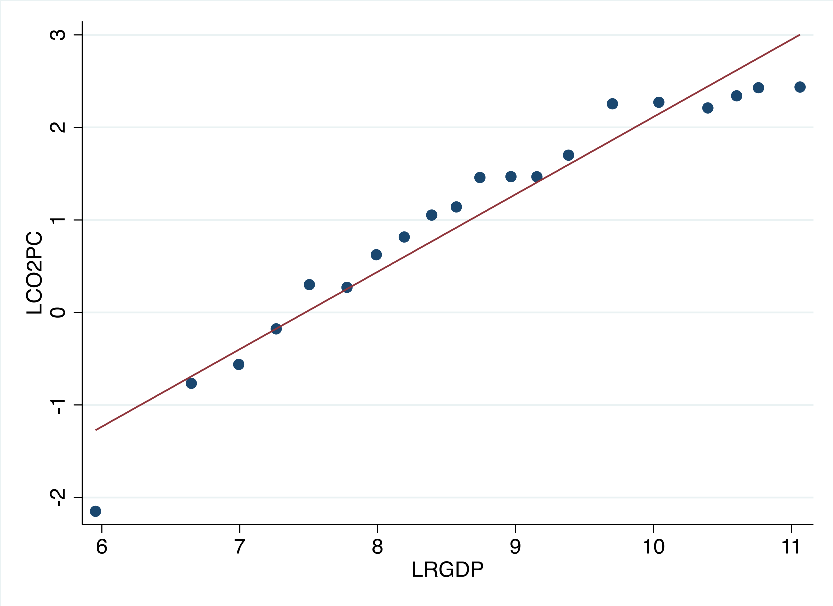
The table below (Table 3) revealed the extent of the relationship (correlation) among the variables of interest (that is, the predictor variables and the predicted variables - CO_2PC). Generally, all the predictor variables, including squared real GDP per capita, significantly (p-value <0.05) has a relationship with carbon emission per capita. All the predictor variables except energy use have a positive association with carbon emission. Furthermore, the predictor variables with the strongest association are real GDP (84.8%) and squared real DGP per capita (82.5%) followed by the economic index with a coefficient value of 55.6%. A closer look within variables also indicates that there is no level multicollinearity (r<70%) among the covariates except real GDP and squared real GDP.

Table 3. Correlation matrix

	LCO2PC	LRGDP	LRGDP2	LAIR	LENU	LCOR	ECI
LCO2PC	1						
LRGDP	0.8478*	1					
	0.0000						
LRGDP2	0.8254*	0.9962*	1				
	0.0000	0.0000					
LAIR	0.4645*	0.5417*	0.5537*	1			
	0.0000	0.0000	0.0000				
LENU	-0.0973*	-0.3826*	-0.3595*	-0.2150*	1		
	0.0000	0.0000	0.0000	0.0000			
LCOR	0.1338*	-0.1633*	-0.1765*	-0.0405	0.2949*	1	
	0.0000	0.0000	0.0000	0.1598	0.0000		
ECI	0.5555*	0.6713*	0.6755*	0.5107*	-0.2565*	-0.1233*	1
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	

Bin scatter plots

Figure 5 below (5a – 5c) revealed the bin scatter plots of all the predictor's variables against the predicted one (carbon emission per capita. Bin scatter plot exposed how data points of the concerned variables are closely fitted to the regression line (Cattaneo et al., 2019). According to Stepner (2014), bin scatter plot explains the precision and standard error of estimates by examining the fitness of the observations to the regression line. The more the observations are fitted to the line, the better the precision of slope estimate and the lower the standard error of such estimates. However, unprecise estimates of slope and high standard error are a result of unfitting observations to the regression line. For example, Fig. 5a – 5d reveals a positive association between the log of carbon emission per capita (CO_2PC) and economic complexities, the log of real GDP per capita, log of air transport, and log of coal rent. This means that both CO_2PC and the just highlighted variables increase at the same time. However, the fitness of the observations indicates the degree of the relationship, the precision of the slopes and the measures of the standard error, thus Fig. 5a – 5c gives better slope and low standard error than Fig. 5d. Lastly, Fig. 5e also indicates the negative association between the log of energy use and carbon emission per capita, the dispersion of the observations from the regression line also indicates the low precision of slope and high standard error of estimates.



LCO2PC
LRGDP
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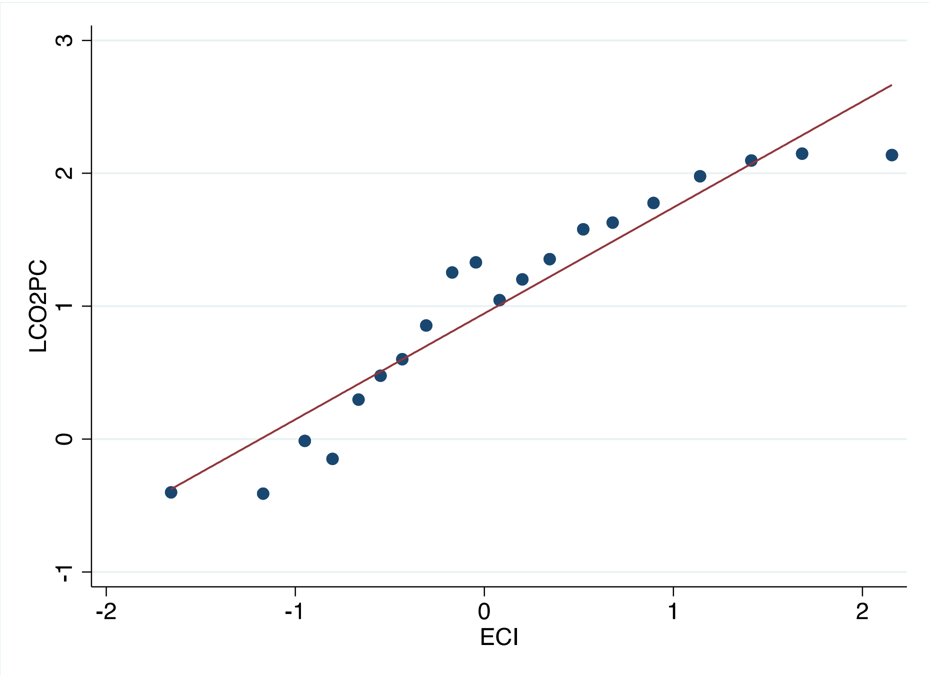
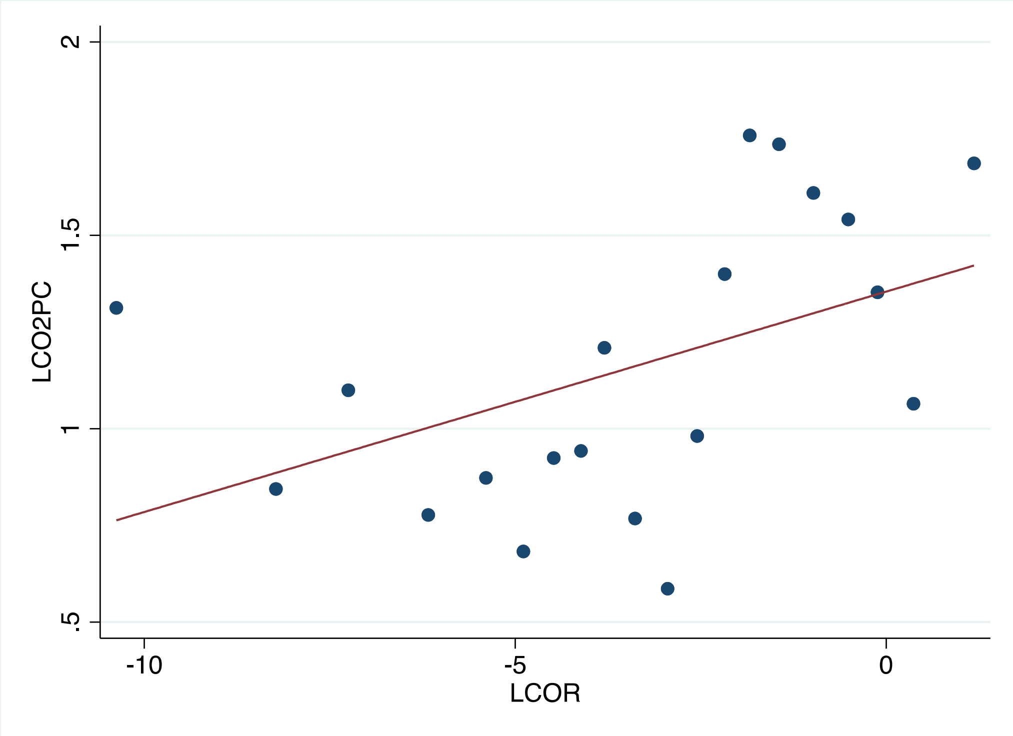
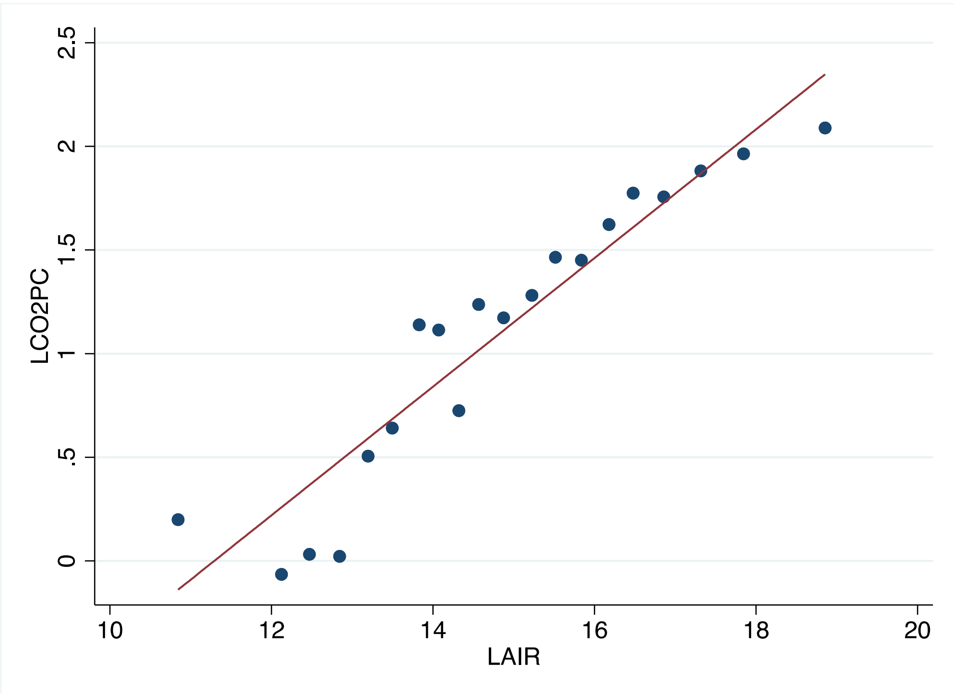
1
0
-1
-2
6
7
8
9
10
11



LCO2PC
ECI
3
2
1
0
-1
-2
-1
0
1
2


LCO2PC
2
1.5
1
.5
-10
-5
0
LCOR


LCO2PC
2.5
2
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LAIR

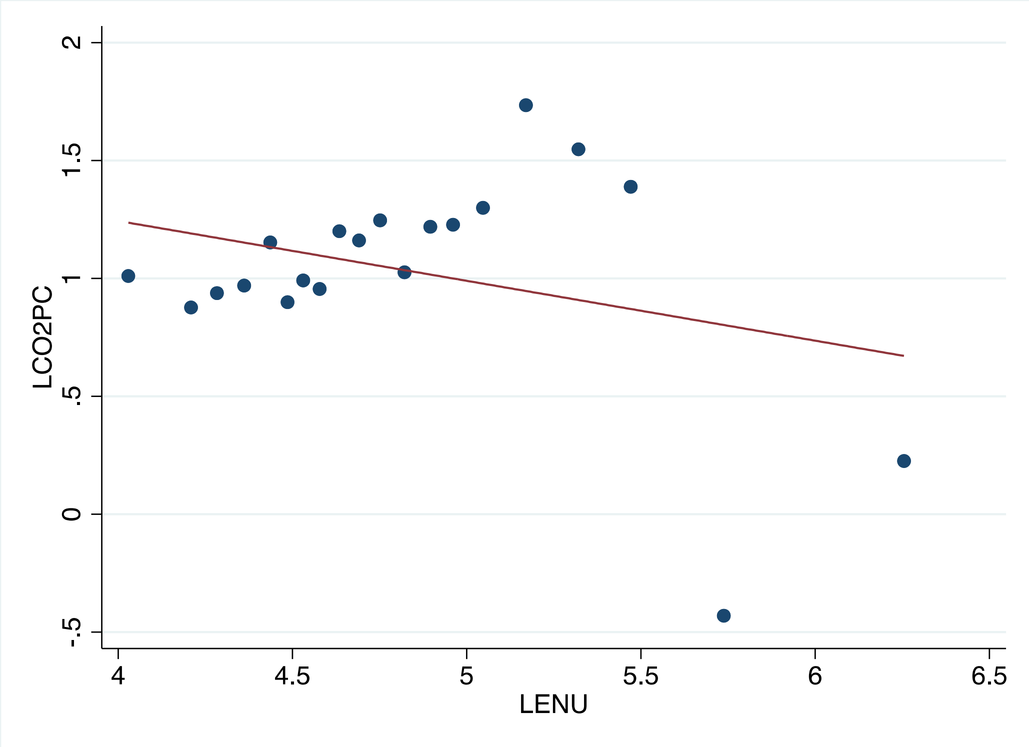

Figure 5. Scatter plot

4.2 Estimation Results

4.2.1. Income groups results

Table 4 and Table 5 show the comparative analysis across the four world bank income groups. The analysis was based on three different models which are pooled OLS (otherwise known as Least Square dummy variables) model in Table 4, and Fixed Effects (FE), and Random Effects (RE) model in Table 5. Starting with the pooled OLS (or LSDV) analysis, the coefficient of real GDP per capita is positive across all the income groups except lower middle-income country. That is 1 per cent increase in real GDP leads to 83.1%, 61.2%, and 18.3% increase in carbon emission for low-income, upper-middle-income, and high-income group respectively, but for the lower-middle-income group, a unit increase in real GDP contribute to 22.4% decrease in carbon emission. Also, these coefficients are statistically significant at the 1% level in upper-middle-income and high-income countries. This outcome is in line with the study of Zhang et al., (2019) and implies that economic growth contributed to the growth of carbon emission in upper-middle-income and high-income countries. On the contrary, the coefficient of real GDP per capita does not significantly contribute to the carbon emission for low-income and lower-middle-income countries. Reverse results were observed for squared real GDP. The coefficient of all the income groups is negative and significant at 10%, 1% and 5% for low-income, upper-middle-income, and high-income group respectively. These indicate that as the squared of GDP increase, the carbon emission will reduce.

For the lower-middle-income group, the coefficient is positive and insignificant. air transport has a positive and significant effect on carbon emission in lower-middle-income and high-income group, negative and significant effect on upper-middle-income, this in line with the study of Tang et al., (2017) which found showed that increase in the scale of tourists and tourism output contributes immensely to the growth of tourism-related carbon emissions. Energy use has a significant relationship, across all the groups, with the carbon emission. A unit increase in energy utilization in lower-middle-income, upper-middle-income, and high-income contribute to 82.2%, 11.9%, and 63.9% increase in carbon emission while it contributes to 21.6% decrease in the low-income group. This result is in tandem with Al-Mulali, Solarin, et al. (2016) and Shahzad et al. (2021) and infers that utilization of energy contributes to high contents of CO_2 emission.

The increase in the usage of coal rents significantly (at 1% level except for low-income group) leads to an increase in high carbon contents in all income groups. Regarding the economic complexities index, its coefficient is positive and significant at 1% and 5% level across all the four divisions of income group. This is an indication that ECI contributes, globally, to the emission of carbon contents to the environment. the goodness-of-fit of the model represented by R-squared value shows that the variability CO_2 that was explained by the predictor variables varies from 63.5% to 88.5% across the income groups.

Table 4. Pooled OLS (or LSDV) for comparative analysis across the 4 World Bank income clusters. (Dep. Variable: CO2PC, log)

	Low Income	Lower Middle Income	Upper Middle Income	High Income
LRGDP	8.318	-2.240	6.121***	1.830***
	(5.303)	(2.150)	(0.932)	(0.580)
LRGDP2	-0.865*	0.224	-0.309***	-0.0717**
	(0.460)	(0.150)	(0.0551)	(0.0287)
LAIR	-0.273	0.101***	-0.0328***	0.0371***
	(0.203)	(0.0367)	(0.00574)	(0.00397)
LEU	-2.162***	0.822***	1.195***	0.639***
	(0.385)	(0.0811)	(0.0294)	(0.0287)
LCOR	0.0497	0.0739***	0.0209***	0.0492***
	(0.0539)	(0.0206)	(0.00607)	(0.00451)
ECI	1.143***	0.298***	0.0328*	0.0460***

	(0.211)	(0.0818)	(0.0190)	(0.0121)
Constant	-3.149	-0.693	-33.66***	-12.46***
	(13.54)	(7.601)	(3.981)	(2.960)
Year Dummies	Yes	Yes	Yes	Yes
Observations	60	273	383	387
R-squared	0.804	0.635	0.885	0.829
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

Based on FE (Table 5) estimation model, the result shows that the coefficient of real GDP is positive and significant (at 1% level) for low-income and upper-middle-income group, the value of the coefficient infer that 1% increase in GDP will result in 82.0% increase in CO_2 for the low-income group and 42.6% CO_2 for the upper-middle-income group. Just like the pooled OLS model, the reverse result is obtained for squared real GDP, the value of the coefficient is negative and significant (at 1% level) for low-income and upper-middle-income group indicating that unit increase in squared GDP denotes certain percentage decrease in CO_2 emission. Also, the coefficient is positive and significant for high-income countries.

Still, on FE estimation, a unit increase in the use of energy significantly contribute to high emission of carbon contents across all the income groups, the emission is most high in upper-middle-income and high-income groups with the value of 90.9% and 99.4% respectively. Unlike ECI's results under pooled OLS estimation, the ECI effects on carbon emission are negative and significant only in upper middle -income and high-income group. The value of its coefficient means that there will be a decrease of 10.6% and 11.4% in carbon exhaustion to the environment as a result of improvement in economics complexities for the people in the concerned group countries. Overall, the amount of variability in CO_2 explained by predictor variables is a good measure since the goodness-of-fit test score ranges between 77.7% and 92.0%.

Based on RE estimation model, the GDP and squared GDP significantly predicted carbon emission in the only upper-middle-income group, but while the coefficient is positive for DGP, it is negative for squared GDP. So, one unit increase in GDP contributes to a 43.5% increase in emission of carbon, and one unit increase in squared GDP contributes to a 19.8% decrease in carbon emission. Similar interpretation, like under the FE model, holds for energy use except that the coefficient of energy use in a low-income country is negative. Also, more coal rent in upper-middle-income and high-income country result in high carbon exhaustion since their coefficient has a positive and significant relationship (at 5% and 10%) with the carbon content. Lastly for

ECI, the value in the low-income country increases carbon emissions at 1% level while it significantly decreases the emission at upper-middle-income and high-income country.

Table 5. Fixed and Random Effects Estimates for comparative analysis across the 4 World Bank income clusters (Dep. Variable: CO2PC, log)

	Low Income	Lower Middle Income	Upper Middle Income	High Income	Low Income	Lower Middle Income	Upper Middle Income	High Income
	Fixed effects				Random effects			
LRGDP	8.209***	0.410	4.261***	-0.0559	8.318	0.416	4.353***	0.357
	(0.205)	(1.219)	(0.978)	(0.676)	(8.781)	(1.282)	(0.990)	(0.732)
LRGDP2	-0.568***	0.0958	-0.192***	0.0622*	-0.865	0.0898	-0.198***	0.0333
	(0.0307)	(0.0903)	(0.0557)	(0.0342)	(0.733)	(0.0958)	(0.0566)	(0.0376)
LAIR	-0.0393	0.00945	0.0418	-0.000544	-0.273	0.0230	0.0309	-0.00233
	(0.0311)	(0.0473)	(0.0312)	(0.00263)	(0.252)	(0.0427)	(0.0263)	(0.00319)
LEU	1.731***	1.334***	0.909***	0.994***	-2.162***	1.267***	0.933***	0.934***
	(0.194)	(0.101)	(0.0649)	(0.0746)	(0.356)	(0.104)	(0.0542)	(0.0831)
LCOR	0.0162	0.0118	0.00949*	0.00909	0.0497	0.0142	0.0106**	0.0113*
	(0.0103)	(0.0141)	(0.00488)	(0.00588)	(0.0601)	(0.0128)	(0.00475)	(0.00608)
ECI	0.0951	0.0599	-0.106**	-0.114***	1.143***	0.0610	-0.107***	-0.0906***
	(0.0933)	(0.0810)	(0.0407)	(0.0283)	(0.343)	(0.0737)	(0.0379)	(0.0342)
Constant	-40.41***	-14.66***	-25.99***	-8.158**	-3.149	-14.21***	-26.30***	-9.128**
	(1.929)	(4.515)	(4.155)	(3.479)	(22.78)	(4.602)	(4.235)	(3.709)
Year Dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
R-squared	0.920	0.777	0.873	0.881				
Number of Country ID	4	16	21	22	4	16	21	22

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.2.2 Combined group estimation

The table 6 below shows the estimation of the combined group by using four different models which are pooled OLS, FE, RE, and system generalized method of moment (GMM) model. From the table, it is revealed that economic growth and square economic are significant predictors of carbon emission per capita at 1% and 5% level of significance. But while the real economic growth leads to an increase in the release of the emission (positive influence on CO_2), the squared economic growth has led to the decrease in the emission (negative influence), thus the models confirmed the EKC hypothesis. Air transport and coal rent have a significant and positive influence on CO_2 under pooled OLS while it is not significant under the other three models. That is a unit increase in the air transport system and coal rent amount to 2% and 7% increase in carbon emission of the studied countries.

Across all the models, the use of energy is positively and significantly influencing the emission of carbon content with the contribution of 2% - 114.7% increase in emission resulting from 1% increase in energy use. The economic complexities under pooled OLS and system GMM model were found to have a positive and negative significant influence on carbon emission per capita the 13.1% increase and little or no decrease respectively. For the pooled OLS and FE model, the goodness-of-fit value indicates that 89.1% and 75.4% variability in carbon emission can be explained by all the indicator variables. Also, the p-value (<0.05) of the Hausman test is an indication that the FE model is the best suitable model among the static models. Furthermore, for the system GMM, the lags of the dependent variable were used to assess the autocorrelation problem, and there is no evidence of second-order autocorrelation since the evaluated Hansen p-value is greater than 5% which leads to the rejection of the presence of autocorrelation in the null hypothesis. Hence, the result obtained from system GMM and FE can be used for inferences.

Table 6. Results for Main Model Estimation across several techniques compared with System GMM (Dep. Variable: CO2PC, log)

VARIABLES	Pooled OLS	Fixed Effects	Random Effects	System GMM
LRGDP	2.864***	2.968***	2.978***	0.162**
	(0.188)	(0.333)	(0.327)	(0.0615)
LRGDP2	-0.123***	-0.107***	-0.109***	-0.00773**
	(0.0100)	(0.0195)	(0.0190)	(0.00295)
LAIR	0.0264***	0.0186	0.0198	0.00291
	(0.00881)	(0.0142)	(0.0137)	(0.00210)
LEU	0.725***	1.147***	1.120***	0.0243*
	(0.0412)	(0.0763)	(0.0726)	(0.0129)

LCOR	0.0707***	0.00318	0.00435	0.00215
	(0.00616)	(0.00537)	(0.00516)	(0.00153)
ECI	0.131***	-0.0500	-0.0426	-0.00800**
	(0.0177)	(0.0382)	(0.0377)	(0.00400)
Lower Middle Income	0.976***		1.255***	
	(0.126)		(0.381)	
Upper Middle Income	1.039***		1.030***	
	(0.143)		(0.373)	
High Income	0.985***		0.512	
	(0.153)		(0.464)	
Constant	-18.87***	-22.22***	-22.86***	-0.906**
	(0.848)	(1.509)	(1.517)	(0.346)
R-squared	0.891	0.754		
Year Dummies	Yes	Yes	Yes	
AR (2) p-value				0.252
Hansen *p-value*				0.1724
Hausman (p-value)		0.000		
Robust standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1				

5. Conclusion and policy implication

The environmental Kuznets curve has been examined significantly in the literature, however, due to increasing levels of complexities of many economies globally, it is vital to consider the role of economic complexities in the EKC. Based on the data on 119 countries from 1995 to 2016 and introducing the economic complexities index alongside other control variables such as air transport, energy use as well as economic growth, squared economic growth, and coal rents as predictors of carbon emission per capita; this paper employed the static model (pooled OLS, FE, & RE) and system GMM methods to examine the global analysis of human-induced consequences of ECI, air transport, and utilization of energy. In a wider sense, the study first assesses whether or not the predictor variables influence the carbon emission among four income groups created by the World bank. Then, using several methods of estimation, the study does the comparative analysis of the combined grouped countries.

The empirical findings suggested (1) that economic growth contributes to the high carbon contents across the income group especially for low-income, upper-middle-income and high-income group, this outcome is in tandem with the study of Solomon and Ngozi (2021) where evidence of increased in environmental degradation in African countries by per capita GDP was firmly established. Similar results hold for squared economic growth, but it contributes to the decrease in carbon emission across the income groups, thus confirming the presence of EKC hypothesis which is in line with a recent study by Nathaniel et al. (2021) where evidence of EKC was established for N11 countries; (2) that the effects of air transport on carbon emission is positive for lower-middle-income and high-income group and negative for upper-middle-income group. This means that increase in the scale of tourists and tourism output contributes immensely to the growth of tourism-related carbon emissions (Tang et al., 2017); (3) that the use of coal rents and energy use leads to high release of carbon contents across all the income groups, and thus fossil fuel energy consumption is associated with high carbon dioxide emission (Shahzad et al., 2021); (4) that significant increase in the utilization of energy for the incomes groups lead to increase in the release of carbon contents except for lower-income group it leads to decrease – this might be because of the low usage of energy in low-income group countries; and (5) economic complexities index increase the carbon emission in low-income groups while it significantly decreases the carbon emission for upper-middle and high-income groups.

Based on the combined groups with relation to the four major predictors (economic growth, air transport, energy use, and ECI), and FE & system GMM model; economic growth and squared economic growth have a positive and negative influence on carbon emission, thus confirming the adoption of Environmental Kuznets Curve hypothesis. Air transport is not significant prediction suggesting that exhaust from air travel does not dampen/upsurges carbon release in the studied countries. The energy use in the countries contributes to the large increase in carbon exhaustion across the two models. Finally, the ECI under system GMM significantly hampers the carbon emission which is in line with the study of Can & Gozgor, (2017) which also discovered that increasing economic complexity index suppresses the emissions of carbon dioxide. The empirical conclusion from the findings provides insight to alleviate carbon emission in the environment. First is that the policymakers or concerned authorities of each income groups should harness the country resources as this make them get doubles of GDP which then while maintaining environmental degradation and sustainability. That is, there is a need for drastic environmental policy measures to drive the focus of reducing the level of carbon dioxide emissions and environmental degradation. Countries should also curb the menace of exhaust from air transport engine and have more control on energy use to reduce the emission, and low-income group countries should synergize on way to make economic freedom for its citizen as this will release carbon content.

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Appendix

Table A.1. List of Countries in Sample

Low Income	Lower Middle Income	Upper Middle Income	High Income
Congo, Dem. Rep.	Angola	Albania	Australia
Ethiopia	Bangladesh	Algeria	Austria
Mozambique	Bolivia	Argentina	Bahrain
Tajikistan	Cambodia	Armenia	Belgium
Tanzania	Cameroon	Azerbaijan	Canada
Togo	Congo, Rep.	Belarus	Chile
Cote d'Ivoire	Bosnia and Herzegovina	Croatia	Cyprus
	Egypt, Arab Rep.	Botswana	Czech Republic
	El Salvador	Brazil	Denmark
	Eswatini	Bulgaria	Estonia
	Ghana	China	Finland
	Honduras	Colombia	France
	India	Costa Rica	Germany
	Indonesia	Dominican Republic	Greece
	Kenya	Ecuador	Hungary
	Kyrgyz Republic	Gabon	Ireland
	Moldova	Georgia	Israel
	Mongolia	Guatemala	Italy
	Morocco	Iran, Islamic Rep.	Japan
	Myanmar	Jamaica	Korea, Rep.
	Nicaragua	Jordan	Kuwait
	Nigeria	Kazakhstan	Latvia
	Pakistan	Lebanon	Lithuania
	Philippines	Libya	Netherlands
	Senegal	Malaysia	New Zealand
	Tunisia	Mauritius	Norway
	Ukraine	Mexico	Oman
	Uzbekistan	Namibia	Panama
	Vietnam	North Macedonia	Poland
	Zambia	Paraguay	Portugal
	Zimbabwe	Peru	Qatar
		Romania	Saudi Arabia
		Russian Federation	Singapore
		Serbia	Slovak Republic
		South Africa	Slovenia
		Sri Lanka	Spain
		Thailand	Sweden
		Turkey	Switzerland
		Turkmenistan	United Arab Emirates
		Trinidad and Tobago	United Kingdom
			United States
			Uruguay