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EXPLORING THE RELATIONSHIP BETWEEN CO2 EMISSION, ECONOMIC GROWTH, AND ENERGY CONSUMPTION AT AGGREGATE LEVEL: A PANEL DATA ANALYSIS

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ABSTRACT

This article explores the relationship between CO2 emissions, economic growth, energy consumption, and, other control factors for the eight highest CO2-emitting countries (USA, Russia, Iran, China, Germany, India, Japan, and Canada) in 1995-2023. The m objective of the study is to determine how economic growth (GDP), energy consumption (EC), industrial production (IP), and other macroeconomic factors influence CO2 emissions. Using panel data analysis, this study applies various econometric techniques, including fixed and random effects models, Multicollinearity tests, heteroscedasticity tests, and cross-sectional dependence tests. Independent variables include GDP, Total energy use, Industrial output, Density of the population, and Trade while the dependent variable is CO2 emission. The results suggest that energy consumption positively correlates with CO2 emission, where, for each unit of energy consumption, CO2 emission increases by 0.0024 units. The outcomes also reveal a negative correlation of international trade with CO2 emissions implying that trade inhibits emissions. However, the relationship between GDP and, carbon emissions was formed to be statistically insignificant. Population density and industrial production have mixed effects on emissions, with industrial production showing a positive impact. The study emphasizes the importance of adopting cleaner energy sources, enhancing energy efficiency, and considering trade policies that might reduce emissions. The findings suggest that transitioning from coal and oil to cleaner energy sources, such as natural gas, could be an effective strategy for reducing carbon emissions without significantly hindering economic growth. The study provides valuable insights for policymakers in high-emission countries aiming to balance economic development with environmental sustainability.

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INTRODUCTION

To tackle the global environmental degradation problem many measures were implemented (Lovett, 2005). The first and foremost principle of the Kyoto Protocol was to turn it into reality. The UNFCC requires developed countries and transforming economies to set differentiated targets used in controlling and minimizing greenhouse gas emissions (Lazăr et al., 2019). All countries have experienced fast economic growth due to the global industrialization process. The increase in energy utilization is the reason for the economic development's rate of growth. CO2 emission increases, through economic growth. Climate change globally is a problem brought on by worsening the problem. Greenhouse gas emissions endanger the existence and well-being of people worldwide—human development, which has turned into a worldwide concern. Issues related to environmental have surfaced globally since the 1960s, prompting governments to allocate increasing funds to address those (Delbeke et al., 2019). The world is familiar with the repeated Ri, and Kyoto Conferences as well as the Copenhagen Conference and the signing of the Kyoto Protocol. By following a high energy intensity path of economic growth, China has become the world's largest consumer of fossil energy, higher than even the USA and its per capita carbon dioxide emission is increasing. To counter these challenges, our government has been keen on cutting down on carbon emissions as propels the Green GDP development model. The strategic goal of the thirteenth five-year plan is to reduce CO2 emissions by 40-45% from 2005 to 2020 and 60-65% by 2030. Thus, it is crucial to develop a low-carbon economy and analyze the connection between energy, the environment, and the economy (Ottinger, 2019), it suggested sustainable development goal of the European Union is among the Europe 2020- objectives. 2030 the strategy for sustainable growth also mentions that all endeavors shall be made by the climate. Steps to decrease absolute GHG emissions by at least 20% and up to 40% by (2020–2030), respectively. These objectives are also aligned with the EU-2050 framework which is aimed at reducing CO2 emissions in the environment. Stressing that all economic sectors should contribute to the achievement of aimed emissions of GHG5 of a decrease in global greenhouse gases up to 80% from the 1990 levels (Lazăr et al., 2019). Similar to how labor and capital are essential to production, and energy plays a big role in manufacturing (Alam et al., 2016). Trade, agriculture, transportation, and economic expansion are just a few of the sectors of the economy that depend on energy. Furthermore, it is believed to have a major positive impact on lowering poverty, advancing human development, and boosting economic prosperity by utilizing various energy sources (Wang et al., 2017). In the process of low-carbon development in various countries, competition between CO2 emissions, income levels, and energy consumption is emerging. This paper expands the spatial Durbin model to analyze economic growth, energy consumption, and CO2 emissions to study not only the cross-dependence and spatial spillover effects between these effects but also the feedback effects. This analysis utilizes panel data from 30 regions from China for the years 2000-2017. The findings demonstrate how economic growth might reduce carbon dioxide emission significantly and China's rate of economic development has emerged as the leading driver of the enhanced emission of carbon dioxide. However, reducing CO2 emissions will not have a major impact on economic growth. There exists a positive linear relationship between energy consumption and CO2 emissions in one direction, and vice versa in the other. We can find a negative spatial spillover because the emissions of carbon and energy are related and considered as a measure of carbon intensity impact on the carbon dioxide emission of the proximate cities and provinces (Zou and Zhang, 2020). Economic growth versus CO2 emission is an area that has been widely covered in the literature. The curve clearly shows the scatter between income disparity and economic development. It is suggested that economic development will exacerbate the gap in income distribution once income hits a certain threshold, but once income surpasses that threshold, income distribution will become more equitable. Based on the Kuznets curve hypothesis, a country's PCI (per capita income) per capita income will add to environmental deterioration up to an extent, beyond which it will not will move up and enhance the environment (Ardakani and Seyedaliakbar, 2019). There are numerous empirical analyses of the link between CO2 emission, energy consumption, and economic growth within regions and across different periods with mixed findings. Recent studies across major economies and developing nations have revealed complex interconnections between these variables. Similarly, in developed countries, other studies by Li et al. (2023) present positive and significant correlation proxies between CO2 emissions and energy consumption in all but two of the developing large emitter countries with different degrees of the relationship. Research works have established that economic development is accompanied by environmental pollution in developing countries, especially in Asia. Research in India (Dhillon & Kaur, 2024) and China (Xie et al., 2023) demonstrated that while energy consumption and GDP positively impact carbon emissions, the effects vary by energy source, with natural gas showing lower emission impacts than coal. African studies present a more diverse picture. Previous research in Sub-Saharan Africa (Kulu et al., 2024) found a strong positive correlation between energy consumption and economic growth, whereas a study in the West African subregion (Donkor et al., 2020) did not establish a link between CO2 emissions, economic development, and renewable energy. Prior research in Southern Africa (Sunde, 2020) established that the nature of the interactions between GDP and energy consumption differs from one country to another. Previous research in developing regions including oil-exporting countries (Apergis, 2016; Bouznit and Romero, 2016; Khan et al., 2020) revealed that economic development and energy used to enhance the levels of CO2 emissions, underlining the importance of efficient energy policies, and shift to green energy.

As we have seen from the discussion above there is confusion as to whether energy consumption is related directly to carbon dioxide emission or whether both energy consumption and carbon dioxide emission affect economic growth. Indeed, the current study makes multiple key contributions toward addressing this knowledge gap by investigating the role of the news media as a source of information about climate change. Additions to the stock of literature already available in the world. First of all, similarly to this study, focusing first on the similarities, the present study also analyzes. The results of the carbon dioxide emissions, energy intensity, and gross domestic product by compared at the high consumption level. Many previous investigations into how the location of their manufacturing plants affects the environmental quality of the world's most polluted economies effectiveness of the integrated model of CO2 emission, energy consumption, and GDP at the macro level.

This analysis aims to explore the relationship between CO2 emissions, energy consumption, and overall economic growth. Many studies examine the relationship between economic development and CO2 emissions. Previous research has explored this connection through the Environmental Kuznets Curve hypothesis, which outlines the link between economic growth and CO2 emissions. More specifically, the primary research question of this study is: What is the overall impact of CO2 emissions on energy consumption and economic growth? The study focuses on eight of the most impacted countries.

METHODOLOGY

This chapter outlines the data sources and methodological approach used to explore the relationship between CO2 emissions, economic growth, and energy consumption at the aggregate level. It begins with a description of the data set, including the countries and period covered, followed by an explanation of the panel data technique employed to analyze the interactions between the key variables. The chapter also discusses the model specifications, the rationale for selecting specific control variables, and the estimation methods used to ensure robust and reliable results. Through this approach, the study aims to provide a comprehensive understanding of the dynamics between environmental, economic, energy, and other factors.

In this study, we use the panel data approach to determine the net impact of CO2 emissions, energy consumption, and economic growth. The collected data span from 1995 to 2023. We must first comprehend the current economic state in terms of economic indicators of the top 8 CO2-emitting countries before delving deeper into the analysis of this study. This study focuses on the macroeconomic conditions of the most polluted countries, which is why they are the subject of our analysis. In addition to other macroeconomic variables, we look at these nations' consumption patterns and emissions, which are significant determinants. We are reviewing the economic conditions of each nation individually, taking into account carbon emissions from start to finish.

Variable Construction

The CO2 emission is the dependent variable that is under investigation in the current study while GDP, population density, industrial production, total energy consumption, and international trade are the independent variables of the aggregate model. This study examines the overall dynamics between CO2 emissions, energy use, economic growth, and industrial output.

Model Specification

This study aims to analyze the total CO2 emissions of countries that rank as the top emitters. The functional form that can be obtained from the aggregated model of the CO2 emissions is as follows Alkhathlan and Javid (2013).

$$CO_{2it} = f(\beta_1 EC_{it}\ ,\ \beta_2 GDP_{it}\ ,\ \beta_3 IP_{it}\ ,\ \beta_4 Z_{it}) \qquad (1)$$

The variables are the carbon emissions represented by CO2 using the metric tons per capita, energy consumption represented by EC using total energy use, economic growth represented by GDP,

industrial production represented by IP using Manufacturing, value added current US$, population density, and international trade represented by X. Whereas, on the one hand, the cross-sectional data and the time series is denoted on the symbols "i,t."
The selection of variables for this research topic is guided by the existing literature and the theoretical model used in this research to establish the links between CO2 emissions, economic growth, and energy consumption.
The dependent variable in this study is CO2 emissions per capita, a well-known indicator of environmental degradation. This variable was selected due to its use in numerous prior studies exploring the relationship between economic growth, energy consumption, and their impact on greenhouse gas emissions (Alam et al., 2016). Gross Domestic Product growth annual percentage is adopted to represent economic growth because it is one of the most frequently used indicators of the economic situation of a country and has been introduced in many studies concerning environmental effects (Ozturk and Acaravci, 2010). Energy use (kg of oil equivalent per capita) is chosen as the index of energy consumption because Total energy consumption is defined as a key factor representing a particular country's level of CO2 emissions (Belloumi, 2009). Manufacturing value added (current US$) as an index of industrial production is also incorporated due to its relation with energy consumption, the potential major driver of emissions (Alam et al., 2016). In addition, population density and international trade are added as the control variables because both factors have effects on economic growth and, environmental changes (Zhang and Cheng, 2009).

$$CO_{2it} = \alpha_0 + \beta_1 EC_{it} + \beta_2 GDP_{it} + \beta_3 IP_{it} + \beta_4 X_{it} + \boldsymbol{\varepsilon} \qquad (2)$$

Econometric Techniques
The term paper used a variety of econometric techniques, including tests for heteroscedasticity, Multicollinearity, Hausman testing, fixed effect and random effect testing, pooled regression analysis, and other tests from the applied econometrics class.

Data and Data Source
For the top 8 CO2 emitter countries (USA, Russia, Iran, China, Germany, India Japan, and Canada) between 1990 and 2023, it includes the impact of CO2 emissions from energy use, economic development, industrial production, alongside other variables of control such as population density, and the share in international trade. The analysis was carried out using the data from the World Development Indicators.

RESULTS AND DISCUSSION
This chapter outlines the results of the panel data analysis to examine the link between the level of CO2 emissions, economic growth, energy consumption, and all other variables under consideration. The findings are also presented in a summary form with preference given to the data description. This is followed by a discussion and interpretation of the results of prior work that seeks to understand the relationship between energy consumption and CO2 emissions, and per capita income at the aggregate level. This chapter also presents the policy implications of these results and discusses any limitations or future research directions.

Descriptive Analysis
The descriptive analysis section explains an overview of the key characteristics of the data used in this study. It includes a summary of the variables under investigation—CO2 emissions, GDP growth, and energy consumption—along with relevant control variables. This section presents basic statistical measures such as mean, median, standard deviation, and trends over time, offering a clear picture of the patterns and variations within the data. By examining these descriptive statistics, we aim to identify initial insights into the relationships between the variables before delving into more advanced econometric analysis.
Table 1 presents the dataset includes six variables, each of which is analyzed over 272 observations: GDP, CO2 emissions, Industrial production (IP), Population density (PD), Energy consumption (EC) and trade as variable X. CO2 emissions also indicate sufficient variation around this mean with a Std. Dev. of 5.30 and mean of 9.33 units. The GDP has an average of 3.16 units, but its 4.27 standard deviation indicates that there are significant variations in the amount of economic output. The state of the economy has a mean of about 3974.79, and a standard deviation of 2416.17 indicates significant variability. The standard deviation of industrial production is 9.36E+11, indicating significant variability in production output, while the average is 6.83E+11. The average population density is approximately 150.51 units, whereas the average value of the trade is roughly 45.61. All things considered, these statistics shed light on the dataset's central tendencies, variability, and ranges of values, pointing to a wide range of environmental and economic factors at work.

Correlation Matrix
This discusses the Correlation Matrix, which is a summary of the various coefficients of the relevant variables selected for the analysis, including CO2 emissions, economic growth, and energy consumption as well as the other control variables. The correlation Matrix is employed to assess the nature and the degree of linear relationships of these variables and would present the researchers the initial perception of the two variables before subsequent testing.
Table 2 indicates the correlations among the variables CO2, GDP, EC, IP, PD, and X. First, there is an evident positive correlation between CO2 and EC, meaning that emissions of carbon dioxide rise in tandem with increases in economic activity or consumption. On the other hand, CO2 and GDP have a somewhat negative correlation, indicating that lower carbon emissions may be linked to higher GDP. Similarly, CO2 and PD have a moderately negative correlation, suggesting that areas with denser populations may have lower CO2 emissions.

Table 1. Descriptive analysis.

Variables	CO2	GDP	EC	IP	PD	X
Mean	9.330932	3.156858	3974.785	6.83E+11	150.5056	45.61265
Median	9.300588	2.773729	3983.656	2.97E+11	87.94309	44.55935
Maximum	20.46980	14.23086	8455.547	5.04E+12	480.9371	110.5996
Minimum	0.647451	-14.5310	351.2121	-8.93E+11	3.088602	15.50626
Std. Dev.	5.298049	4.271577	2416.172	9.36E+11	148.2525	19.25323
Observations	272	272	272	272	272	272

Table 2. Correlation matrix.

Correlation	CO2	GDP	EC	IP	PD	X
CO2	1.000000	-0.381882	0.969537	0.223453	-0.593450	0.088288
GDP	-0.381882	1.000000	-0.391815	-0.007293	0.121014	-0.094749
EC	0.969537	-0.391815	1.000000	0.132187	-0.591874	0.180174
IP	0.223453	-0.007293	0.132187	1.000000	0.048777	-0.257752
PD	-0.593450	0.121014	-0.591874	0.048777	1.000000	-0.195895
X	0.088288	-0.094749	0.180174	-0.257752	-0.195895	1.000000

The moderately negative relationship between GDP and CO2 raises the possibility that lower carbon emissions are related to higher GDP. But in contrast to the correlation between EC and CO2, this correlation is weaker. Furthermore, there is a weak negative correlation between GDP and EC, suggesting a somewhat negative relationship between GDP and economic consumption.

There is a moderately negative correlation between EC and PD, suggesting that areas with higher economic consumption may have lower population densities. This result might be explained by urbanization trends, which focus on economic activity in densely populated areas.

There appears to be a marginally positive correlation between industrial production and carbon emissions, as indicated by the weak positive correlation that IP, or industrial production, has with CO2. Conversely, there is a weak but positive correlation between IP and PD, suggesting that areas with higher industrial production may also tend to have higher densities of population.

Finally, there is only a very weak positive correlation between the variable X and CO2, suggesting that there is little relationship between the two. Moreover, it shows marginally negative correlations with GDP, IP, and PD, indicating somewhat negative relationships with these factors. On the other hand, it exhibits a marginally positive correlation with EC, suggesting a slightly positive relationship with economic consumption.

Panel Least Square Regression Model

This section presents the results obtained from applying the Panel Least Squares (PLS) Regression Model, which was utilized to explore the link between several key variables: CO2 emissions, GDP, population density, industrial production, total energy consumption, and international trade. The PLS model enables a detailed examination of how these factors interact over time and across different countries, accounting for both individual country-specific characteristics and temporal effects.

The results offer insights into how economic growth, energy consumption, and industrial production contribute to CO2 emissions, while also considering the influence of population density and international trade. The inclusion of these control variables allows for a more nuanced understanding of the broader macroeconomic context and helps identify any significant correlations between energy use, economic development, and environmental impact.

In the following sections, the authors present the Panel Least Squares Regression results, as indicated in Table 3. The study showed that a one-unit increase in GDP when other variable inputs are controlled reduces CO2 emissions by approximately 0.0206 units. For example, the study by Abbasi et al. (2022) on the Kuznets curve in light of the members of the European Union resulted in a positive and meaningful connection between CO2 emission and economic growth. The authors explained that a USD 1% rise in gross domestic product corresponded to a 0.65% rise in carbon dioxide emissions. The coefficient of Energy consumption (EC) is estimated to be very low, 0.002038. It implies that with every unit increase in energy use, there is likely to be a 0.002 unit incremental in the level of CO2 emission. The coefficient for population density is -0.002121. Hence, there is a moderate correlation between population density and CO2 emissions where a unit rise in population density is associated 0.0021-unit decrease in CO2 emissions. The coefficient of variable X (Trade) is -0.019367This indicates that for any standardized value of trade, an increase in one unit leads to decay of approximately 0.0194 units of the CO2 emissions. Our overall test for the regression model shows an F-statistic of 1139.721, and a p-value of 0.0000, which means the model is significant. C coefficient which is the intercept term of the current model is equal to 2.169562, which means the model will predict an overall average level of CO2 emissions if all independent variables have a value of zero. The coefficient of R square value being 0.955404 shows that about 95.54% of the changes observed in CO2 emissions can be accounted for by the independent set of variables adopted in the equation.

Table 3. Panel least square regression model.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	-0.020627	0.017708	-1.164816	0.2451
EC	0.002038	3.96E-05	51.44490	0.0000
IP	4.83E-13	7.81E-14	6.179248	0.0000
PD	-0.002121	0.000591	-3.591165	0.0004
X	-0.019367	0.003794	-5.104382	0.0000
C	2.169562	0.307108	7.064488	0.0000
R-squared	0.955404			
Adjusted R-squared	0.954565			
F-statistic	1139.721			
Prob(F-statistic)	0.000000			

Lagrange Multiplier Tests for Random Effects

In this section, the Lagrange Multiplier (LM) Tests for Random Effects as used in panel data analysis are highlighted to establish the most suitable model for specification.

Table 4. Lagrange multiplier tests for random effects.

Test	Cross-section	Test Hypothesis Time	Both
Breusch-Pagan	261.6443 (0.000)	13.19094 (0.0003)	274.8353 (0.0000)

Table 4 provides the results of the Breusch-Pagan LM test. Here for cross-section, the values are significant, time value is also significant. What does it mean, it means that we have to select way random and fixed effect model. These results show that OLS is not appropriate for a model.

Random Effect Estimation

In this section, we present the findings of the Random Effect Estimation used to account for heterogeneity across the countries apart from controlling for the temporal variations in the panel data. The Random Effects model: Here individual specific effects are independent of the explanatory variables so that more efficient estimation is possible only if this assumption is valid. In this way, it is possible to examine the dynamic that connects CO_2 emissions, economic growth, and energy consumption with the country's factors while using regression analysis.

Table 5. Random effect estimation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	0.012924	0.016630	0.777131	0.4378
EC	0.002192	6.27E-05	34.96797	0.0000
IP	2.99E-13	8.23E-14	3.633401	0.0003
PD	-0.000547	0.001078	-0.507775	0.6120
X	-0.021522	0.004490	-4.792995	0.0000
C	1.435368	0.421408	3.406126	0.0008

In terms of GDP, it is shown in Table 5 that a one-unit increase in the GDP implies a 0.012924-unit increase in CO_2 emissions estimated from the GDP coefficient. However, at the traditional thresholds ($p > 0.05$), this relationship is not statistically significant. It is suggested that the energy consumption coefficient is 0.002192, It means therefore that, one unit of energy used leads to the emission of 0.002192 units of CO_2. This relationship is highly statistically significant at $p = 0.001$. By evaluating the coefficient of industrial production, it suggests that there is almost no relationship between the industrial production of one unit and/or the emission of CO_2. There is a significant correlation between them here at .005 levels. The study reveals that the level of PD is highly significant to CO_2 emissions; as the level of PD increases by one unit, CO_2 emissions decrease by 0.000547 units. Trade and CO_2 emissions are inversely related in that one unit of trade reduces emissions of CO_2 by 0.021522 units.

Hausman Test

In this section, we report the Hausman test results for deciding whether we should use the Random Effects or Fixed Effects models for the analysis of the panel data. The Hausman test is used to compare the results from both models to establish if the random effects have a relation with the deterministic variables.

Hypothesis construction

H0: Random effect is appropriate

H1: Fixed effect is appropriate

Table 6. Correlated random effects - Hausman test.

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	25.356068	5	0.0001

In Table 6, we have explained the Hausman test through which the right model is fixed or random effect. If we look at the probability value which is equal to 0.0001 % less than 5%. This is so because the theoretically generated null hypothesis is rejected in favor of the theoretical or the alternative hypothesis which shows that the fixed effect is appropriate.

Fixed Effect Model Estimation

In this section, the findings from the Fixed Effects Model Estimation have been provided because this method of estimation controls for individual-specific characteristics that are time-invariant but may differ across countries. The Fixed Effects model maintains the heterogeneity endogeneity by only using panel-level variance hence diminishing the influences of the characteristics of countries that remain constant to arrive at correct estimates of the various control variables such as CO_2 emissions economic growth energy consumption amongst others. With the help of this model, plurality is possible to compare changes within key variables and the results on CO_2 emission within each country in the given period.

Table 7 depicts the fixed effect model estimation results. The GDP coefficient (0.014961) indicates that a rise of one unit in GDP corresponds to a lead of 0.014961 units in CO_2 emissions; however, this is not statistically significant at conventional levels (p-value = 0.3873). For instance, the recent study by Olanrewaju et al. (2022) entitled; 'The environmental cost of economic growth in Sub-Saharan Africa' revealed that an increase is positively related to the GDP at a significant level.

Table 7. Fixed effect model estimation.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
GDP	0.014961	0.017278	0.865923	0.3873
EC	0.002408	0.000104	23.17175	0.0000
IP	2.05E-13	9.09E-14	2.260227	0.0246
PD	0.000926	0.003052	0.303345	0.7619
x	-0.022183	0.005491	-4.039794	0.0001
C	0.446230	0.551161	0.809619	0.4189

The authors indicated that for each one percent change in GDP, there was a corresponding 0.88 percent change in the amount of carbon dioxide emissions and this was statistically significant at p= 0.01. For instance, Dong et al. (2022) in a study on the environmental Kuznets curve in China discovered that using the level of income as a driver of carbon dioxide emissions was more considerable at higher per capita income levels. This suggests that the relationship between these variables may not be linear and may depend on the specific context and stage of economic development.

The coefficient 0.002408 for energy consumption is highly significant which reveals that there is a very strong positive association between energy usage and CO2 emissions. In particular, a one-unit increase in energy consumption leads to a 0.002408-unit increase in carbon emissions. This discovery points to the usage of energy as a dominant destructive force on the natural environment, something that underscores the importance of policies and strategies geared towards energy efficiency, optimal utilization of energy, and conversion to clean sources.

The findings specified that there is a positive relationship of industrial production with CO2 emissions, at a coefficient of 2.05E-13. This implies that changes in the manufacturing and industrial activities, and the value added in the manufacturing sector have a direct impact on carbon emissions. This emphasizes the need to adopt sustainable production processes and technologies in the industrial dimension of the economy to embrace sustainable economic activities.

The regression result highlights an inverse correlation between trade and CO2 emissions, at -0.022183. This means that for every one-unit increase in trade, trade reduces carbon emission by 0.022183 units. This result implies that liberalization of international trade could reduce the negative effects on the environment possibly through technology transfer, outsourcing of polluting industries, and exploitation of gain from cleaner production.

Cross-Section Dependence Test

In this section, we perform the Cross Section Dependence Test to determine if error terms in our panel data are correlated or dependent across sections.

Table 8. Cross-section dependence test.

Test	Statistic	d. f.	Prob.
Breusch-Pagan LM	199.4389	28	0.0000
Pesaran scaled LM	22.90948		0.0000
Bias-corrected scaled LM	22.78827		0.0000
Pesaran CD	2.575638		0.0100

Ho: There is no cross-sectional, dependence; H1: There is a cross-sectional dependence.

The result of the test is presented in Table 8 for testing Cross-sectional dependence it gives a probability value of less than 0.05% to reject the null hypothesis and infer Cross-sectional dependence exists in the data. Hence all three tests done which include; Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD all supported this because all its p values < 0.05%.

The diagnostic tests for cross-sectional dependence for the panel data model are shown in Table 8. The p-values of the Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD < 0.05 which indicates that the error terms in the panel data model are correlated across the sample countries. This has specific attitudinal implications on the generalization of the findings of this study. This is especially important since cross-sectional dependence means that the observed relations may be valid only for the broader group of countries analyzed and cannot be applied to other conditions or countries in the same region (Chudik and Pesaran, 2015).

Multicollinearity Test Estimations

In this section, we present the results of the Multicollinearity Test Estimations, which are conducted to assess whether there are high correlations among the independent variables in the model.

Table 9. Multicollinearity test estimations.

Variable	VIF	1/VIF
EC	2.66	0.375501
PD	1.64	0.611293
GDP	1.51	0.661521
IP	1.43	0.700020
X	1.14	0.880702
Mean VIF	1.676	

In Table 9 we have checked the multicollinearity among the variables. If we look at the VIF values, the mean value of VIF which is 1.676 is less than 5. It means that there is no multicollinearity among independent variables in the regression.

Heteroscedasticity Test Estimations

In this section, we present the results of the Heteroscedasticity Test Estimations, which are conducted to detect any issues with unequal variance of the error terms across observations in the panel data.

Table 10. Heteroscedasticity test estimations.

Heteroscedasticity	Value	df	Probability
Likelihood Ratio	187.7198	8	0.0000
LR Test Summary			
	Value	df	
Restricted Logl	-415.9926	266	
Unrestricted LogL	-322.1327	266	

In Table 10 we have checked the heteroscedasticity among the variables. From the above table, the probability value is less than 0.05, which indicates that there is no heteroscedasticity in this model.

Linearity of the Variables

In this section, we examine the linearity of the variables in the model to ensure the relationships between the variables (CO2 emissions, GDP, population density, industrial production, total energy consumption, and international trade).

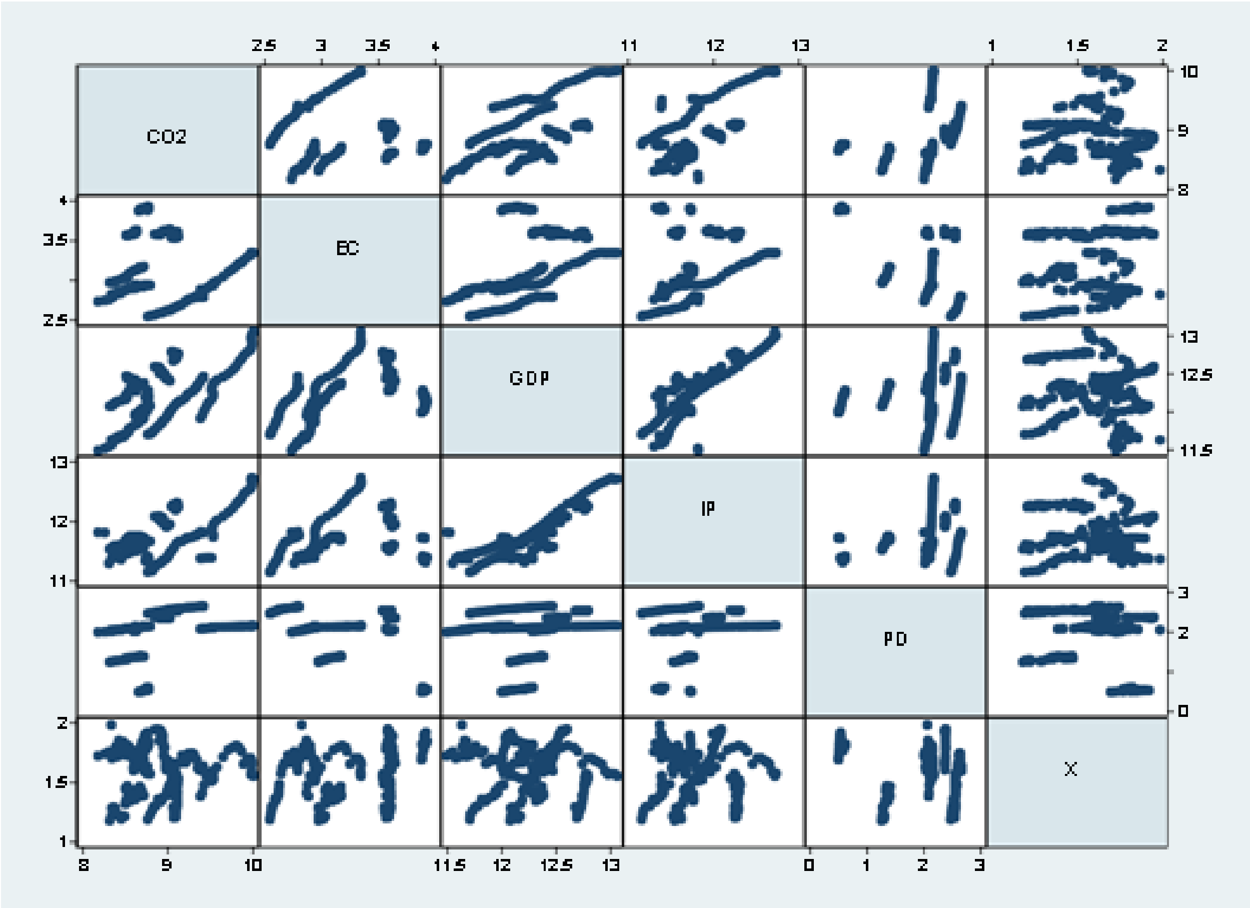

Figure 1. Linearity of variables.

Figure 1 shows the linearity among dependent and independent variables. The results show that energy consumption, GDP, and industrial production have a linear relationship with carbon emissions. Whereas population density and trade are non-linear concerning carbon emission.

CONCLUSION AND RECOMMENDATIONS

The above discussion suggests that the coefficients imply that there is an average of a 0.0206 reduction in CO2 emissions for each one-unit increase in GDP controlling the other factors. The coefficient for Energy Consumption (EC) is 0.002038. This gave an implication that, for each unit increase in energy usage, there is an approximately 0.002-unit increase in CO2 emission unit. However, the population density (PD) coefficient is -0.002121%. This means that there is a correlation on average between a co-efficient of 0.0021 decrease in CO2 emissions and a +1 increase in population density. From the analysis, we have got the coefficient of variable X (Trade) = -0.019367. From the regression results shown above, it can be inferred that a one unit change in trade means an equivalent change of roughly 0.0194 in CO2 emissions, ceteris paribus. When we checked which model was suitable for fixed and random effect models when we undertook the Hausman test then we found that the fixed effect model is suitable. Table 7 represents the estimation of the fixed effect model to quantify the results. Estimation of GDP coefficient resulted in 0.014961 showing that an increase of one unit of GDP is accompanied by a 0.014961-unit increase in CO2 emissions but the coefficient is insignificant at conventional levels (p-value = 0.387361). The coefficient for energy consumption 0.002408 most critical indicates that the increase in energy consumption, by one unit causes 0.002408 units increase in CO2 emissions. CO2 emissions have a positive relationship with Industrial production (IP) with a coefficient of 2.05E-13. Results show that there is an inverse relationship between exports and CO2 emissions since X (Trade) is statistically negative. We also reported that there is a presence of cross-sectional dependence because all the tests Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD statistically significant their probability value is less than 0.05%. The test for Multicollinearity and heteroscedasticity detected that there is no auto, metro, and MC among the variables. In the end, we applied the linearity test to detect which variables are linear and which are not. The results show that energy consumption, GDP, and industrial production have a linear relationship with carbon emissions. Whereas population density and trade are non-linear relations with carbon emission. The policy suggestion is that to decline environmental degradation, the top emitter countries and other nations need to increase the consumption of gas which may help to reduce carbon emissions. The move from Oil which is also known as coal to gas in the production process factors will contribute to reducing the pressure on Oil prices and will intern tweak the prices and other economic goods and services. For clean energy use, there must be the best pricing of the products that are in the markets for them to smoothly rotate in their quests. In a way, the pressures may be eased on the oil prices while experiencing construction through the passage from oil or coal to gas to be used in the production process and that may put a bearing on the prices of all the economic goods and services. Nevertheless, to switch to clean energy, it is necessary to understand that proper pricing for the products of alternative energy is quite important for a stable operation of the market. However, this policy suggestion is not without its drawbacks, changing to a natural gas energy source may be counterproductive in so many ways for example; increased reliance on nonrenewable energy sources, the effects on the environment from the extraction and transportation of the gas, and social impacts to societies that may depend on coal or oil as their main source of power. Moreover, all economic consequences associated with such a change, such as the impact on employment and industries, are worthwhile contemplating. Thus, it is crucial to agree on the limitations and implications of a particular proposal to formulate the appropriate strategy that would help transition to a cleaner and more sustainable energy supply.

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