EFFECT OF ECONOMIC DEVELOPMENT ON ENVIRONMENTAL POLLUTION: A COMPARATIVE ANALYSIS BETWEEN DEVELOPED AND DEVELOPING COUNTRIES

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Abstract

Environmental pollution is a critical factor worldwide due to the enhanced frequency and severity of natural disasters and catastrophes, and it crucially affects the survival of the universe. Hence, the study focused on the impact of economic growth on environmental pollution. This research study comparatively analyzes the impact of economic growth on environmental pollution in developed and developing countries and it investigates the impact of economic growth and environmental pollution. The study incorporated a data series over the period of 1980-2022 of 50 countries. The panel data regression analysis employed in this study to analyze the impact of economic growth on the environmental pollution which are proxied using the Gross Domestic Product Growth rate and the Carbon Emissions (CO2) metric tons per capita with the control variable incorporated the energy consumption. In addition, the researchers assessed the Environmental Kuznets Curve (EKC) theory in the study to provide an in-depth understanding of the study field. Further, the study revealed a significant positive impact of economic growth on environmental pollution in the developing countries. The study supports the validity of the EKC theory in explaining the relationship between economic growth and environmental degradation. Hence, establishing environmentally friendly economic policies and practices are highly appreciated to lower environmental pollution and to shrink the adverse effects of economic growth on environmental pollution in the developing countries. These research findings highlight the importance of sustainable practices, environmental regulations, and collaborative efforts to mitigate the negative impacts of economic development on the environment. This study serves as a foundation for future research in this critical area to have a sustainable environment in the future while having a coherence between the lower emission rates and the higher economic growth rates.

Keywords: Carbon Emission; economic growth; environmental pollution; environmental Kuznets curve; gross domestic product growth.

1. Introduction

Economic development has been the primary force behind the rapid growth of societies around the world. On the other hand, striking a balance between economic development and the conservation of the natural environment is a significant challenge. The complex relationship between economic development and environmental pollution has become a subject of growing attention in terms of sustainable development (SDGs) and the well-being of future generations. This thesis aims to explore the impact of economic development on environmental pollution. By examining the interplay between these two critical areas, we can gain a deeper understanding of the complex consequences that arise from the pursuit of economic growth.

Environmental pollution refers to the presence or introduction of harmful substances into the environment that causes adverse effects on the natural world and the health of living organisms, including humans. Pollution can come from various sources and can occur in different forms(Ukaogo et al., 2020). Increased environmental protection risk from economic actions and activities undertaken for economic development has become a global problem. Economic development and environmental protection are one of the major challenges facing humanity today(Shoaib et al., 2020). Economic development can have both positive and negative effects on environmental pollution. The relationship between economic development and environmental pollution is complex and can vary depending on various factors, such as the stage of development, technological advancements, government policies, and societal awareness(Chen et al., 2021). Economic development often involves industrialization, which can lead to increased pollution. Industries release pollutants into the air, water, and soil through their production processes. Factories that burn fossil fuels for energy pose risks to human health and ecosystems by releasing greenhouse gases and other pollutants that contribute to climate change and air pollution(Zhao et al., 2018).

As economies grow, there is usually an increase in industrial production, consumption, and overall economic activity. This growth often leads to higher carbon emissions. Industries that rely on fossil fuels such as coal, oil, and natural gas emit carbon dioxide (CO2) and other greenhouse gases (GHG) during energy generation and production processes. Increased economic activity, particularly in sectors such as manufacturing, transportation, and construction, can increase energy demand and carbon emissions. Energy consumption is a major driver of carbon emissions. Most of the global energy production is still heavily dependent on fossil fuels. When fossil fuels are burned for electricity generation, heating, transportation, and other purposes, they release CO2 into the atmosphere. High levels of energy consumption, in particular, directly

contribute to increased carbon emissions (Osobajo et al., 2020).

Developed countries generally have high levels of energy consumption due to their advanced industrial sectors, transportation systems, and high living standards. Developing countries are experiencing rapid economic growth and industrialization, resulting in increased energy consumption. Developed countries have historically contributed significantly to global carbon emissions due to their long-term industrialization and economic growth. However, many developed countries have attempted to reduce carbon emissions through clean technologies, energy efficiency measures, and policy interventions. Developing countries are becoming major contributors to global carbon emissions as their economies expand. In the pursuit of economic development, energy consumption from fossil fuel sources often increases, leading to higher carbon emissions. However, developing countries are increasingly recognizing the importance of sustainable development and are taking steps to reduce emissions and switch to cleaner energy sources. Both developed and developing countries contribute to global carbon emissions, and their energy consumption, economic development, and policy responses differ. Developed countries often have lower carbon emissions per unit of economic output due to cleaner technologies and policies, while developing countries produce more carbon emissions with faster economic growth (Chen et al., 2021).

Promoting sustainable economic growth worldwide requires a comprehensive strategy and international cooperation that includes measures to reduce emissions and adapt to the impacts of climate change. Finding the strategy should also include research and development (R&D).

1.1. Problem Statement

This research aims to study and compare how economic growth affects environmental pollution in developed and developing countries. Economic development often involves industrialization, which can lead to increased pollution. One of the main ways economic growths affects pollution is through energy consumption. Energy consumption is a significant driver of carbon emissions. The factories that burn fossil fuels for energy release greenhouse gases and other pollutants that contribute to climate change and air pollution. This impact on human health and ecosystems has become a global problem today(Shoaib et al., 2020).

Energy consumption is everywhere in the world in both developed and developing countries. The extent and nature of this impact may vary depending on their technology, government policies, and industrialization readiness. Understanding the impact of economic growth on environmental pollution is

critical for policymakers, researchers, and stakeholders to develop effective strategies and policies for sustainable development.

Therefore, it is necessary to do this study to know how economic growth affects environmental pollution in developed and developing countries.

1.2. Research Questions

I. Does economic development in developed and developing countries affect their environmental pollution?
II. How do economic development and energy consumption affect CO2 emissions in developed countries?
III. How do economic development and energy consumption affect CO2 emissions in developing countries?
IV. What are the strategies to reduce the impact of economic development on pollution in developed and developing countries?
V. How do policies and strategies to reduce pollution in developed countries affect financial costs?

1.3. Objectives of the Study

Specific objectives:

- To identify the impact of energy consumption and economic development on CO2 emissions in selected developed and developing countries.
- To compare how the behavior of economic growth in developed and developing countries affects environmental pollution.
- To provide strategies to reduce CO2 emissions by reducing energy consumption in developed and developing countries based on empirical findings of the study.

General Objectives:

- To understand how the consequences of economic growth affect environmental pollution in developed and developing countries.
- To provide recommendations for governments, businesses, and other stakeholders to reduce the negative impact of pollution from excessive energy use on economic growth.
- To evaluate the effectiveness of existing policies, laws, and regulations to reduce environmental pollution and promote sustainable

development.

- To explore the role of international cooperation in addressing the economic consequences of environmental pollution in developed and developing countries.
- To identify research and knowledge gaps on the relationship between economic growth and environmental pollution and prioritize areas for future research.

1.4. Significance of the Study

- Research helps increase our understanding of the complex relationships between economic growth and environmental pollution.
- Research helps identify specific areas where economic growth has the most significant impact on pollution, such as particular industries or regions with high energy consumption.
- Research can provide important information that can be used to inform policy decisions aimed at reducing pollution and promoting sustainable development.
- Studying the impact of economic growth on pollution in developed and developing countries can promote international collaboration in research and share best practices among countries.
- Overall, research on the impact of economic growth on pollution can provide valuable insights that can be used to promote sustainable development, improve public health, and enhance economic growth.

1.5. Limitation of the Study

- Data on pollution and economic growth can be difficult to obtain. Especially in developing countries where data collection and reporting systems are underdeveloped.
- The relationship between corruption and economic growth is complex and can be influenced by a wide range of factors such as economic policies, demographics, and culture, making it difficult to isolate the effects of corruption.
- The effects of economic development on environmental pollution can be long-term and not immediately visible, making it difficult to study and understand.
- World Bank (WB) data cannot be guaranteed to be 100 percent accurate. Because the data is completely based on econometric modules, tools, outputs, and software packages, there is a possibility of technical errors.
- Measuring the development level of countries is a complex task that involves considering various indicators. Classification as developed or

developing countries is not static and may change over time as countries progress and develop.

- When selecting developed and developing countries, HDI rankings are not an absolute measure of development and do not capture all aspects of well-being or sustainability. They provide a general assessment of a country's development but may not reflect specific nuances or challenges within each country

2. Literature Review

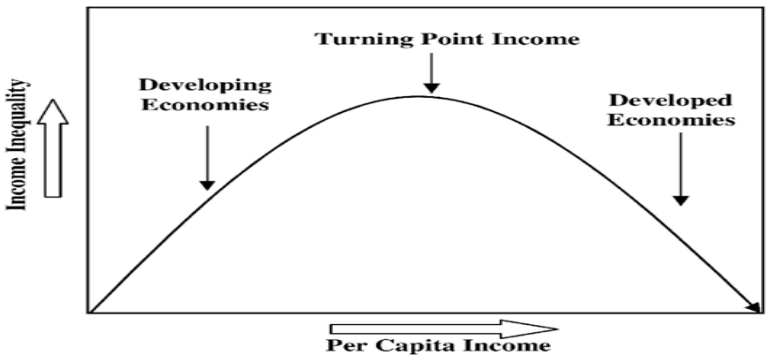
2.1. Theoretical Review

2.1.1. Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC) is an economic theory that proposes a specific relationship between environmental degradation and economic development. It assumes an inverted U-shaped curve representing the relationship between per capita income or economic growth and various environmental indicators.

EKC theory suggests that environmental degradation worsens when countries experience industrialization and urbanization in the early stages of economic development. This initial phase is characterized by increasing levels of pollution, deforestation, and resource depletion as economic activity intensifies. As income increases, the demand for goods and services increases, leading to increased production and consumption, often at the expense of the environment.

Figure 1: Environmental Kuznets Curve



However, as countries reach a certain income threshold or level of economic development, EKC theory suggests that environmental degradation begins to decrease. Beyond this turning point, further economic growth goes hand in hand with an improvement in environmental quality. Factors such as increased awareness, technological advances, policy interventions, and a shift in consumption patterns to cleaner and more sustainable practices can lead to a reduction in environmental degradation.

EKC theory has been applied to various environmental indicators, including air and water pollution, deforestation, loss of biodiversity, and carbon emissions. Researchers have examined empirical data from various countries to examine the existence and shape of EKC. However, findings are mixed, indicating that the relationship between economic growth and environmental degradation is complex and context dependent. Overall, EKC theory provides a framework for understanding the relationship between economic growth and environmental degradation (Kong & Khan, 2019).

2.2. Empirical Review

Empirical findings show that energy consumption has a positive relationship with carbon emissions (Zhu et al., 2016). Further empirical findings show that there is a positive relationship between per capita energy consumption and per capita GDP in Central Asia, which indicates that economic growth in the region is highly dependent on energy consumption. However, per capita CO2 emissions have a negative impact on per capita GDP, researchers say. Additionally, they state that there is a negative relationship between per capita GDP and per capita energy consumption (NGUYEN, 2019). Environmental regulation and concentration of high energy-consuming industries show positive effects on environmental pollution, with long-term effects outweighing short-term effects (Wang & Zhou, 2021).

The empirical findings indicate the existence of an inverted U-shaped relationship between carbon dioxide emissions and GDP per capita (Kais & Sami, 2016). A study revealed a reciprocal causal relationship between economic growth and energy consumption, indicating that they influence each other. Additionally, a unidirectional causal relationship was observed between energy consumption to CO2 emissions and suggesting that energy consumption contributes to the generation of CO2 emissions (Wang et al., 2016). Empirical findings from another study demonstrated a substantial positive relationship between energy consumption and economic growth, both of which were found to have a significant impact on CO2 emissions (Osobajo et al., 2020).

Research suggests that adopting policies aimed at enhancing energy efficiency

and mitigating air pollution is crucial for fostering sustainable economic development (Nathaniel & Khan, 2020). These studies highlight the detrimental effects of air pollution on economic development, albeit with variations in the magnitude of impact depending on the level of economic development and the specific type of pollution being considered(Ali & Puppim De Oliveira, 2018).

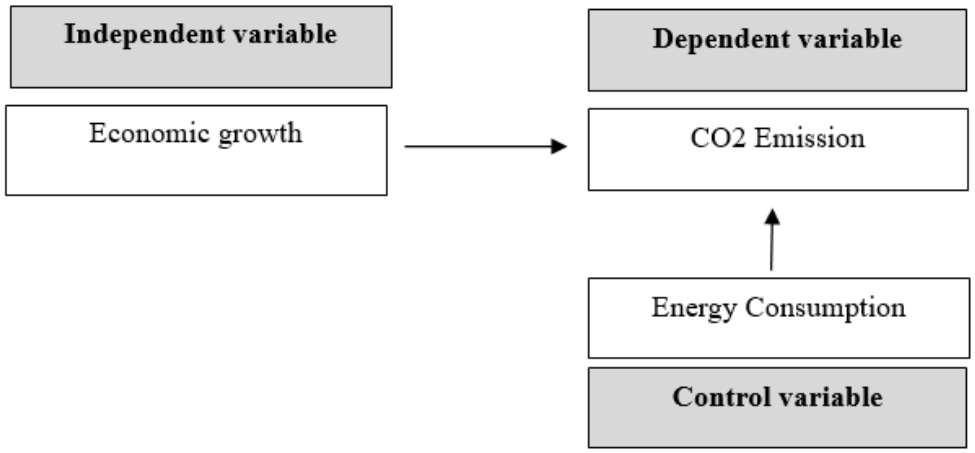
3. Research Methodology

3.1. Conceptual Framework

The overall idea of the variables used for this study has been shown through the conceptual framework. According to the research topic, how economic development effect environmental pollution will be analyzed here. Accordingly, economic development used as independent variables and carbon emissions as dependent variables. And There is a control variable call energy consumption.

The main objective of this research is to analyze the relationship between these variables and their influence on each other. Accordingly, it has been mapped and shown how the variables of the study come together to reach those conclusions.

Figure 2 Conceptual framework author constructed.



3.2. Conceptualization and the Variables of the Study

Table 1 Measurement indicators of variables

Variables	Measurement indicators
Energy Consumption (ECN)	Fossil fuel energy consumption (% of total)
Economic Growth (GDP)	GDP growth (annual %)
Carbon Emission (CO2)	CO2 emissions (metric tons per capita)

Source: EViews output

3.3. Research Hypotheses

H1: There is a significant impact of energy consumption on the CO2 emissions in developed countries.

H2: There is a significant impact of energy consumption on the CO2 emissions in developing countries.

H3: There is a significant impact of economic growth on the CO2 emissions in developed countries.

H4: There is a significant impact of economic growth on the CO2 emissions in developing countries.

3.4. Research Design
3.4.1. Purpose of the Study

The research questions of the study focus on understanding the impact of economic development on environmental pollution in both developed and developing countries, as well as the strategies to reduce this impact. The objectives of the study include identifying the impact of energy consumption and economic development on CO2 emissions, comparing the behavior of economic growth in developed and developing countries, providing strategies to reduce CO2 emissions based on empirical findings, and evaluating existing policies and

regulations to promote sustainable development.

3.4.2. Sources of Data

The data source on which this research is based is the World Development Indicators (WDI). The World Bank compiles and publishes a wide range of development indicators and data through its World Development Indicators (WDI) database. These indicators cover socio-economic topics such as poverty, education, health, economic growth, infrastructure, pollution, and many more. The World Development Indicators database is collected from a variety of official sources, including national statistical institutes, international organizations, and research institutes.

However, data availability and accuracy may vary across countries and indicators. The World Bank and other international organizations strive to ensure the accuracy and reliability of the data they compile, but limitations and discrepancies may exist due to differences in data collection methods and reporting practices across different countries.

3.4.3. Population and Sample Selection

In this study, the population consists of all countries, and they are categorized into two groups: developed and developing. The purpose of this categorization is to compare the effects of economic development on environmental pollution between these two groups.

From this population, a sample is taken to conduct the study. The sample includes a total of 50 countries, with 25 countries randomly selected from each category (developed and developing). The sample is chosen to represent a smaller subset of the population and is intended to be representative of the characteristics and trends observed in the larger population.

3.4.4. Data and Data Collection Method

This study will utilize secondary data analysis to conduct a quantitative analysis. The data collection method involves accessing and extracting the relevant data from the World Bank reports for the specified time. It will gather secondary data from reports issued by the World Bank spanning the period from 1980 to 2022.

3.4.5. Data Analysis

To achieve the objectives of the research study, which is to examine the impact of economic development on environmental pollution in developed and

developing countries, the data analysis of this study is done using panel data regression. Specifically, Excel is used for data organization, and EViews software for panel data regression analysis.

Descriptive statistics are used first in the data analysis process. Descriptive statistics will be calculated to summarize and describe key features of the data. This includes measures such as means, medians, standard deviations, and other statistical measures that provide insight into the central tendency and variability of the variables under study. Then the unit root test will be performed. Before conducting panel data regression analysis, it is essential to check for unit roots in the variables. Unit root tests help determine whether variables are stationary or show a trend over time. This step is important to ensure the reliability and validity of the regression results. Next, correlation analysis can assess the strength and direction of relationships between variables. This analysis helps identify any significant relationships between economic development and environmental pollution.

The next analysis is panel data regression. Panel data regression is a statistical method used to analyze data with both cross-sectional and time-series dimensions. It allows the examination of individual and time-specific effects on the dependent variable(s). EViews will be used to perform panel data regression analysis. It will help quantify the relationship between economic development and environmental pollution while controlling for other relevant factors.

Finally, hypothesis testing will be done. Here the specific hypotheses derived from the research objectives will be tested. Hypothesis testing is the comparison of observed data with expected results based on the null hypothesis and the alternative hypothesis. These measures help evaluate the statistical significance of the findings and determine whether the relationships between economic development and pollution are statistically significant.

By adopting this data analysis approach, researchers aim to uncover insights into the relationship between economic development and environmental pollution, provide evidence, and support or refute stated hypotheses

4. Results and Discussion

4.1. Descriptive statistics Analysis

Table number 2 and 3 respectively show the mean values of each variable used to study the impact of economic development on environmental pollution in developed and developing countries in this research.

Table 2: Descriptive analysis of developed countries

Developed countries					
Variables	Mean	Median	Maximum	Minimum	Std. Dev.
GDP	2.271912	2.358342	24.37045	-14.5311	3.549563
ECN	79.53004	85.23325	99.39174	25.11710	17.45717
CO2	8.870413	8.405999	20.46981	2.160457	3.482039

Source: EViews output

Table 3 Descriptive statistics of developing countries

Developing countries					
Variables	Mean	Median	Maximum	Minimum	Std. Dev.
GDP	4.011974	4.372019	57.81783	-64.0471	6.720315
ECN	70.28467	75.70916	99.80444	5.051140	24.20856
CO2	2.740651	1.847998	13.27041	0.047919	2.270997

Source: EViews output

The presented tables provide a comprehensive summary of the descriptive analysis conducted on a dataset comprising more than 800 observations. The analysis reveals that the mean value of the CO2 variable in developed countries is 8.870413, whereas, in developing countries, it is 2.740651. This discrepancy

indicates that, on average, developed countries exhibit higher levels of CO2 emissions compared to developing countries. The descriptive analysis reveals that the mean value of the energy consumption (ECN) variable in developed countries is 79.53004, while in developing countries, it is 70.28467. This discrepancy suggests that, on average, developed countries exhibit higher levels of energy consumption compared to developing countries. The analysis reveals that the mean value of the economic growth (GDP) variable in developed countries is 2.271912, whereas, in developing countries, it is 4.011974. This contrast in mean values suggests that, on average, developing countries experience higher rates of economic growth compared to developed countries. It is important to consider that further statistical analysis may be necessary to assess the significance of these differences between countries.

4.2. Correlation Analysis

Tables 4 and 5 provide an overview of the correlation analysis conducted for developed and developing countries, respectively.

Table 4 Correlation analysis of developed countries

Developed countries		
Variables	Correlation (CO2)	Probability (CO2)
GDP	-0.013161	0.7145
ECN	0.398859	0.0000

Source: EViews output

Table 5 Correlation analysis of developing countries

Developing countries		
Variables	Correlation (CO2)	Probability (CO2)
GDP	0.168613	0.0000
ECN	0.649893	0.0000

Source: EViews output

According to the correlation matrix presented in Table 4, the correlation analysis of developed countries reveals important findings. At a 95% confidence interval, there exists a positive correlation of 0.398859 between energy consumption (ECN) and CO2 emissions. This correlation is not only positive but also statistically significant, as evidenced by the p-value of 0.0000, which is less than the predetermined significance level of 0.05.

Furthermore, in developed countries, a positive correlation of 0.013161 is observed between economic growth (GDP) and CO2 emissions. However, this correlation is not statistically significant, as the associated p-value of 0.7145 exceeds the significance level of 0.05. Thus, the evidence does not support a significant relationship between economic growth and CO2 emissions in this context.

Moving to Table 5, which focuses on developing countries, the correlation analysis yields significant results. At a 95% confidence interval, there is a positive correlation of 0.649893 between energy consumption (ECN) and CO2 emissions. This correlation is not only positive but also statistically significant, as indicated by the p-value of 0.0000, which falls below the predefined significance level.

Moreover, a significant negative correlation of -0.168613 is observed between economic growth (GDP) and CO2 emissions in developing countries. This negative correlation is statistically significant, as the associated p-value of 0.0000 is below the predetermined significance level.

4.3. Unit Root Test

Table 6 showed the probability values obtained from the unit root tests conducted on each variable in the study of economic growth effect on environmental pollution in developed and developing countries.

Table 6 Unit root analysis of developed & developing countries.

Developed countries		Developing countries	
Variables	Probability	Variables	Probability
GDP	0.0004	GDP	0.0000
ECN	0.0001	ECN	0.0000
CO2	0.0059	CO2	0.0000

Source: EViews output

The output obtained through Levin, Lin & Chu panel unit root test by unit root analysis is shown in Table 6 above. Accordingly, the probability value of the carbon emission variable (CO2) in developed countries is shown by 0.0059, energy consumption (ECN) by 0.0001, and economic growth (GDP) by 0.0004. All those values are obtained through Levin, Lin & Chu panel unit root test and the values are less than 0.05 in the level test. Accordingly, the alternative hypothesis can be accepted by confirming that the data series of developed countries is stationary.

The probability value of the carbon emission variable (CO2) in developing countries is 0.0000, and energy consumption (ECN) is 0.0000, obtained through Levin, Lin & Chu panel unit root test and the values less than 0.05 are stationary in the level test. Also, economic growth (GDP) has been stationary at less than 0.05 in the first difference test obtained through Levin, Lin & Chu panel unit root test from 0.0000. Accordingly, the alternative hypothesis can be accepted by confirming that the data series is stationary in developing countries as well.

Overall, all the probability values in developed and developing countries show less than 0.05. Accordingly, these probability values are stationary, and the alternative hypothesis is acceptable. The alternative hypothesis can be accepted

because the entire data series is stationary and the resulting data series is not unit root. Therefore, a panel data regression analysis can be performed.

4.4. Panel Data Regression Analysis

Tables 7 and 8 present the results of the panel data regression analysis conducted separately for developed and developing countries, respectively.

Table 7 Panel data regression analysis of developed countries

Developed countries		
Variable	Coefficient	Probability
GDP	-0.024872	0.44450
ECN	0.080043	0.00000
Constant (C)	2.561132	0.00000
R-squared	0.597261	
Adjusted R-squared	0.575492	
Prob(F-statistic)	0.000000	
Durbin-Watson stat	1.632131	

Source: EViews output

As shown in Table 7, the effect of independent variable (GDP) on the dependent variable (CO2) is shown numerically according to the coefficient of developed countries. Accordingly, if ECN changes by one unit, then it has a positive impact of 0.080043 on CO2 and if GDP changes by one unit, then it has a negative impact of -0.024872 on CO2.

Table 8 Panel data regression analysis of developing countries

Developing countries		
Variable	Coefficient	Probability
GDP	0.045029	0.00000
ECN	0.060278	0.00000
Constant (C)	1.315333	0.00000
R-squared	0.640062	
Adjusted R-squared	0.638612	
Prob(F-statistic)	0.000000	
Durbin-Watson stat	1.803793	

Source: EViews output

As shown in Table 8, the effect of the independent variables (GDP) on the dependent variable (CO2) is shown numerically according to the coefficient of developing countries. Accordingly, if ECN changes by one unit, then it has a positive impact of 0.060278 on CO2 and if GDP changes by one unit, then it has a positive impact of 0.045029 on CO2.

Hypothesis Testing

Aligning with the developed hypothesis based on the literature review, Table 9 showed the accepted and rejected hypotheses in the study considering the outputs in Tables 7 & 8.

Table 9 Hypothesis testing

Hypothesis	P-value	Status
H1: ECN significantly impact on the CO2 emissions in developed countries.	0.00000	Accepted
H2: ECN significantly impact on the CO2 emissions in developing countries.	0.00000	Accepted
H3: GDP significantly impact on the CO2 emissions in developed countries.	0.44450	Rejected
H4: GDP significantly impact on the CO2 emissions in developing countries.	0.00000	Accepted

Source: EViews output

4.5. Developing Final Fitted Model

The final fitted models provide valuable insights into the relationships between the independent and dependent variables and can be used for prediction, hypothesis testing, and decision-making purposes.

Table 10 shows the final fitted models for both developed and developing country categories according to the final fitted model created by the regression researcher based on the identified long-run relationships.

The basic Final Fitted Model can be developed as follows,

$CO2_{it} = C + \beta 1\ ENC_{it} - \beta 2\ GDP_{it} + \varepsilon_{it}$

$CO2_{it}$ = Dependent Variable

C = Constant value

$\beta 1\ ENC_{it}$ = Coefficient of one independent variable (ECN)

$\beta 2$ GDPit = Coefficient of one independent variable (GDP)

εit = Error term

Table 10 Final fitted model.

Basic Model	$CO2_{it} = C + \beta_1 ENC_{it} - \beta_2 GDP_{it} + \varepsilon_{it}$
Model 1: Developed countries	$CO2_{it} = 2.561132 + 0.080043 ECN_{it} - 0.024872 GDP_{it} + \varepsilon_{it}$
Model 2: Developing countries	$CO2_{it} = -1.315333 + 0.060278 ECN_{it} - 0.045029 GDP_{it} + \varepsilon_{it}$

Source: EViews output

4.6. Confirming EKC Theory

According to the analyzed data (Table 7), panel data regression analysis proved that energy consumption in developed countries has some positive significant effects on carbon emissions. But it was confirmed that economic growth has no effect on carbon emissions, i.e., it has a negative effect. Also, according to the analyzed data (Table 8), the panel data regression analysis proved that energy consumption in developing countries has some positive significant effect on carbon emissions, and economic growth also has a negative but significant effect on carbon emissions.

These findings are consistent with the theoretical expectations of the EKC hypothesis, which suggests that the relationship between energy consumption, economic growth, and carbon emissions follows an inverted U-shaped pattern as countries experience economic development and income growth. Initially, energy consumption and carbon emissions increase as countries undergo industrialization and urbanization. However, as income levels continue to rise, the negative effects of economic growth with the implementation of environmental regulations and advances in technology lead to a decrease in carbon emissions(Ridzuan et al., 2022).

5. Conclusion

According to the descriptive analysis findings, on average, developed countries exhibit higher levels of CO2 emissions. And, on average, developed countries exhibit higher levels of energy consumption. But on average, developing countries experience higher rates of economic growth compared to developed countries.

Correlation analysis can help assess whether these observed differences are statistically significant or occurred by chance alone. Specifically, in developed countries, energy consumption demonstrates a significant positive correlation with CO2 emissions, while economic growth does not exhibit a significant relationship with CO2 emissions. In contrast, in developing countries, both energy consumption and economic growth show significant correlations, with energy consumption positively associated with CO2 emissions and economic growth negatively associated with CO2 emissions.

All the unit root probability values in developed and developing countries show less than 0.05. Accordingly, these probability values are stationary, and the alternative hypothesis is acceptable. By assessing the stationarity of the variables through unit root tests, researchers can ensure the appropriate application of panel data regression models and draw reliable conclusions from their analyses.

Panel data regression analysis shows that ECN & GDP of developed countries are positively and negatively affected by CO2 respectively. Its ECN probability value is significant and GDP value is not significant. Also, in developing countries ECN & GDP positively and negatively influence CO2 respectively and both variables have a significant impact on CO2.

Accordingly, whether to accept or reject the formulated hypotheses is decided according to the probability value of the regression analysis. According to it, among the constructed 4 hypotheses, hypotheses 1, 2, and 4 are accepted, and hypothesis 3 is removed from the model.

The results obtained from this analysis will contribute to the existing body of knowledge and provide valuable insights for policymakers and researchers in the field. These results provide valuable insights into the environmental consequences of economic development in both developed and developing countries and promote a more environmentally friendly path of economic growth by emphasizing the need for sustainable policies and practices to reduce carbon emissions.

6.Future Research Directions

Finally, this research study emphasizes the need to address pollution through environmental regulations, sustainable practices, waste management, clean technologies, and public awareness. Limitations of the study such as the complexity of the topic and challenges associated with data accuracy must be acknowledged. These limitations provide opportunities for future research to delve deeper into this important area of study.

According to that, can conduct research to analyze the economic impact of pollution by exceeding identified thresholds and using other variables. Future studies can explore alternative data sources, employ advanced data collection methods, and collaborate with international organizations to improve data quality and access. And examining the role of technological advancements and innovation in mitigating environmental pollution can be a promising avenue for future research.

Overall, this research study lays the foundation for further analysis and investigation in subsequent chapters. It contributes to existing knowledge on the relationship between energy consumption, economic growth, and carbon emissions and provides valuable insights for policymakers and researchers striving for a more sustainable and environmentally conscious future.

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