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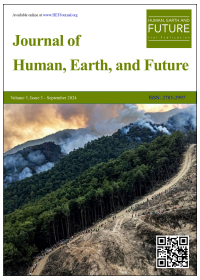

Investigating the Impact of Economic Growth on Pollution Index in Emerging Market Countries

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Abstract

This research aims to provide answers to two problems: to analyze the influence of economic, ecological, and demographic variables on environmental quality and which variables of the three have more influence on environmental quality. Using panel data analysis, with 24 Emerging Markets countries as the research objects and a series for the period between 2013 to 2022, it was found that: (a) the variables of economic growth, greenhouse gases, petrol consumption, and population influence the pollution index, while carbon emissions have no significant effect on the Pollution Index in Emerging Market countries; (b) the variables that have the greatest influence on the pollution index in emerging market countries are ecological and demographic variables compared to economic variables. Based on the findings, the implications for policy implementation are: (a) providing understanding to the public about ecology; (b) increasing population must be balanced with increasing education for the community to provide information about maintaining environmental quality; and (c) directing a sustainable economic development model in all countries through an appropriate and consistent policy framework. Theoretically, this research contributes to sharpening and understanding the flow of thinking of the Environmental Kuznets Curve (EKC) theory.

Keywords: Pollution Index; Sustainability; Environment; Economy; Emerging Market Countries.

1. Introduction

Economic growth is an indicator of the macroeconomic performance of countries in the world. Countries have made efforts to achieve high economic growth, and many of them followed the policy of increasing the production of goods through industrialization. However, humans often forget about our Earth's limited capacity to accommodate and fulfill various human needs. When fulfilling their needs and desires, human often exceeds Earth's carrying capacity, which will ultimately threaten nature and even the future survival of humans and other creatures. Encroaching on Earth's capabilities means that human pressure on the environment has become greater than the ability of Earth's natural systems to absorb human pressure, and the result is major changes in the function of Earth's ecosystem. These changes in turn will also threaten human welfare and even their survival [1].

Previous studies have shown that economic growth drives increased carbon dioxide (CO_2) emissions through energy consumption [2-4]. However, there are other studies suggesting that emissions are not drivers of economic growth and

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that CO_2 emissions can reduce the rate of economic development at a very high cost through health burdens and decreased productivity of human resources [5, 6]. Based on the results of research in several countries, it was found that environmental quality is positively influenced by economic growth [7-9]. However, several other studies have shown that economic growth has a negative impact on environmental quality [10, 11]. In addition, research related to the impact of economic growth on environmental quality showed that there is a significant influence, in which the higher the economic growth, the better the CO_2 emissions on environmental quality. This is because the process of developing a country's economy to improve people's welfare requires the management of natural resources. Other studies have painted a different picture, where in the short term, increasing or decreasing CO_2 emission pollution takes a long time because changes in the structure of a country's economy take a long time [9]. Regardless of the different environmental indicators used by researchers, the results of their empirical studies showed that the positive or negative relationship between economic growth and environmental quality is still inconclusive.

Greenhouse Gas (GHG) emissions are a form of pollution caused by the presence of several types of gases in the atmosphere which can absorb and retain solar radiation, causing the temperature on Earth's surface to increase. According to the UN convention (UNFCCC), six types of gases are classified as greenhouse gases: (CO_2), (CH_4), (N_2O) (HFCs), (PFCs), and (SF6). The most abundant greenhouse gases in Earth's atmosphere are carbon dioxide (CO_2), methane (CH_4), water vapour (H_2O), nitrous oxide (N_2O), and other gases. Research results show that the higher the increase in greenhouse gas emissions, the warmer the Earth. Increased greenhouse gas emissions led to an increase in the ability of the Earth's atmosphere to retain the sun's heat and prevent it from leaving the atmosphere. This consequently resulted in global warming and more extreme climate change, including increasing global average temperatures, melting polar ice caps, and changes in unstable weather patterns [12]. Uncontrolled changes in temperature and climate automatically have negative impacts on various economic and social activities, such as reduced agricultural production, slow distribution of goods and services, natural disasters, disease outbreaks, and pandemics caused by GHG emissions.

The increasing number of vehicles, followed by increasing fuel consumption, also increases the fuel burned, resulting in pollutants that are dangerous for life. These pollutants are CO, CO_2, and HC emissions. The main source of pollution comes from the transportation sector, where almost 60% of the pollutants produced consist of carbon monoxide (CO) and around 15% consist of hydrocarbons (HC). Apart from the production aspect, excessive consumption of petroleum in recent times has also had a broad impact on various sectors of life, especially on-air quality and pollution. In addition, the continuous burning of fossil fuels due to oil consumption also has a negative impact on the environment. Air quality decreases due to smoke from burning fuel oil containing dangerous gases such as CO, NOx, and UHC (unburned hydrocarbon), as well as metal elements such as lead (Pb). The effect of greenhouse gas emissions caused by CO_2 gas from burning petroleum causes global warming. Thus, the use or consumption of fuel for transportation and industry has negative externalities through three pathways, which are oil consumption, oil production, and the effects of greenhouse gas emissions due to burning oil fuel. Empirical studies have found that the relationship between CO_2 emissions and energy consumption is remarkably close, implying that these countries have maintained a fixed consumption pattern of fuels that cause carbon intensity. They also show that additional efforts are needed to find cleaner energy production methods and achieve a more sustainable economy [13]. As an effort to reduce carbon emissions caused by the combustion of fossil fuels, they are currently being diverted to gas fuels because using gas fuels is more environmentally friendly than premium fuel. The specific level of emission reduction for gas-fuelled vehicles compared to gasoline is 60%–80% CO, 30% CO_2, and 80%–90% ozone-producing reactivity.

Human needs are always increasing due to the increasing human population. As a result, Earth is no longer able to support human needs. One form of Earth's limitation, which is pollution, has become a major problem and is an ongoing concern. The impact of population growth is the increasing need for energy and CO_2 emissions [14]. The relationship between population and environmental degradation is increasingly gaining attention. High population density would also have an impact on high demand for natural resources such as water and fossil fuels and increase pressure on environmental capacity [6]. Todaro and Smith show theoretically how population density is related to environmental degradation. If population density and world income levels increase, then environmental conditions will continue to deteriorate due to degradation problems. Rapid population growth and expansion of economic activity in developing countries are likely to cause extensive environmental damage unless steps are taken to mitigate the negative impacts. In this regard, this study aims to analyze the relationship between population density and environmental quality.

Referring to the various empirical evidence above, the influence of economic growth on environmental quality with various indicators still shows inconclusive results, which suggests that there is still a fairly wide research gap regarding the problem. Theoretically, the explanation of the relationship between economic growth and the environment can be explained by the Environmental Kuznets Curve (EKC). Based on the EKC, the negative impacts on the environment tend to dominate in the initial stages of economic growth, but the positive impacts of the composition and engineering effects that tend to reduce emission levels dominate in the decline stage [15]**.** EKC states that the inverted U-shaped relationship between income and CO_2 means that in the initial stages of development, environmental degradation occurs, but at a certain point, increasing economic development will reduce CO_2 emissions [16, 17].

Based on these main problems, this research aimed to analyze the effect of economic and non-economic growth on the pollution index in Emerging Markets countries. Therefore, this study used a more comprehensive approach by accommodating three aspects in particular: economy, ecology, and demography. By combining these variables, this study could provide significant new contributions to the literature and policy practices regarding the relationship between economic growth and the environment, which is the pollution index, especially in emerging market countries. This study attempted to answer the question, what variables are the most dominant in influencing environmental problems? Ultimately, the answer may provide a solution in the form of policies that could address the current environmental problems.

2. Literature Review

In recent decades, the relationship between economic growth and environmental degradation has been a major concern in the economic literature. These major concerns can be grouped into three types: (a) production and consumption behavior, (b) decreasing natural resource reserves, and (c) decreasing environmental quality due to increasing pollution. Regarding the behavior of production and consumption of natural resources and energy, it is necessary to pay attention to several problems that can damage the environment, one of which is plastic pollution, which is a major threat to our planet and oceans [18]. However, as our knowledge increases, more people are aware of the importance of environmental sustainability. They begin trying to save the environment for environmental sustainability and from depending on human behavior [19]. This has led to a new lifestyle for many, which includes the switch from processed food to organic food [20].

One study examined research trends on the relationship between economic growth and environmental degradation. It used a quantitative exploratory methodology and performed a bibliometric analysis of articles registered in the Scopus and Web of Science databases from 1972 to 2022. The data shows a significant increase in the number of publications and authors examining the application of the Kuznets curve to ecological footprint and carbon emissions indicators, which is considered the most significant factor. It also showed that there is an inverted U-shaped correlation between economic growth and environmental degradation. In particular, it underlined the negative contribution of inadequate consumption of natural resources, especially non-renewable energy, to environmental degradation. Overall, these implications underscore the urgency of collective efforts to address this critical issue [21].

Another study linked production behavior with environmental degradation and examined the impact of economic growth and FDI on environmental degradation in Indonesia through a two-hypothesis model. Environmental degradation is often linked to economic growth and FDI needed by developing countries. Based on externality theory, this study used the EKC hypothesis, followed by pollution havens vs. hallo pollution. The results of this study support the EKC and pollution haven hypotheses. First, for the EKC hypothesis model, this study found that economic growth in the initial stages increases environmental degradation, but economic growth after the turning point will reduce ecological degradation. In addition to testing the EKC hypothesis, renewable energy consumption can reduce environmental degradation caused by carbon emissions. Second, the pollution hypothesis model showed that increasing FDI can increase ecological degradation, thereby supporting pollution havens. This research suggested that policymakers should require foreign investors to implement green economy concepts supported by a green taxonomy and provide fiscal incentives to those who do so [22].

A study on the impact of rapid economic development on air quality was conducted in Dubai, United Arab Emirates (UAE). Dubai is one of the fastest-growing cities in the world, with a population increase of approximately 80x over the past 60 years. Concentrations of five criteria air pollutants (CAPs), including carbon monoxide (CO), nitrogen dioxide (NO_2), and particulate matter less than 10 μm in diameter (PM10), ozone (O_3), and sulphur dioxide (SO_2), were studied from 2013 to 2021 at 14 regulatory monitoring stations. The results showed that the largest increase in air pollution was for the primary air pollutants NO_2 and SO_2, with reductions of 54% and 93%, respectively, over the studied period. Gross domestic product (GDP), population growth, and energy consumption were significantly and negatively correlated with NO_2 and SO_2 and strongly and positively correlated with PM10. CO was positively correlated with the number of completed buildings, while the results for O_3 were inconclusive. The trends of NO_2 and SO_2 indicate that these two pollutants are not related to economic development, which supports the Environmental Kuznets Curve hypothesis of the relationship between economic growth and environmental degradation with caution. The improvement in the city's air quality was due to the implementation of effective local environmental policies, which are not affected by large-scale development and urbanization. Monthly assessments of Dubai's air pollution for 2019 and 2020 showed a 3–16% increase related to COVID-19 in the levels of studied air pollutants, except for ozone, which increased by an average of 8% [23].

Regarding natural resource reserves, they are related to the need for raw materials and energy for sustainable economic growth in the future, mainly because reserves are decreasing. Energy consumption plays a particularly key role in the economic development of a country. Countries in Asia, both developing and developed, have significant differences in terms of energy consumption and its impact on the economy [24]. The energy crisis, especially low access

and affordability, mismatch between demand and supply, energy gap, and high dependence on non-renewable energy sources, become challenges before achieving clean energy goals for sustainable development [25].

A study examined the relationship between economic growth and energy consumption in the period 1986–2015 for 15 selected developed countries. According to the results of the cointegration test, it has been determined that there is a long-term relationship between economic growth and energy consumption. The results obtained from the Dumitrescu-Hurlin causality test analysis show that there is a two-way causality relationship. It was concluded that economic growth and energy consumption are causes of each other for the period 1986–2015 in 15 selected developed countries [26].

A study examined three factors influencing CO_2 emissions in Kazakhstan. The fact that these factors explain 16.1% of the variability in CO_2 emissions is a valuable finding that suggests the accuracy of the selected variables. The causal relationship between renewable energy consumption and CO_2 emissions is important for the contribution of renewable energy investments to CO_2 emissions. In addition, the absence of statistical significance in the relationship between CO_2 emissions and industrial production index and economic growth demonstrates that industrial development and economic growth can be achieved without major concerns about CO_2 emissions. The results of the research show that economic growth does not have a significant effect on CO_2, but CO_2 emissions are an important variable in the environmental quality index. Another study found that CO_2 emissions greatly influence energy consumption, added value in the industrial sector, household final consumption expenditure, and added value in both the agricultural and service sectors [27].

Although financial growth does not necessarily result in increased environmental damage, the use of sustainable energy can reduce CO_2 emissions. Furthermore, it was found that financial trends influence sustainable energy use bilaterally. Increased trading activities can result in higher energy use and CO_2 emissions, thereby endangering the environment. The importance of sustainable energy in national energy portfolios must be addressed to gain real benefits from trade agreements [28].

Long-term demand for sustainable energy will be driven by economic expansion and international trade. However, whether increasing sustainable energy consumption can help address environmental problems depends largely on how CO_2 emissions will change as the economy grows. As a long-term relationship, increasing the use of sustainable energy has an impact on global trade. This establishes that future economic growth, global trade, and technological advances in the environmental sector are expected to facilitate and encourage the use of sustainable energy in each country [29].

The next issue related to economic growth and the environment is the decline in environmental quality caused by increasing pollution in air, water, and land. The impact of decreasing environmental quality globally is global warming and climate change, the biggest cause of which is the year-to-year increase in carbon emissions. Emissions are the most important indicator of environmental awareness and sustainability [30]. Controlling CO_2 emissions begins with controlling the factors that influence these variables. The impact of environmental degradation on human health and plant and animal life has prompted politicians, researchers, and organizations such as the OECD to address this problem.

A study explored the influence of economic policy uncertainty on environmental quality in selected MENA countries relying on an augmented STIRPAT model over the period 1970–2020. The ARDL model and its extensions, such as the augmented ARDL, augmented NARDL, and MTNARDL models, were applied to detect the possible effects of uncertainty indices on carbon dioxide (CO_2) emissions. Empirical results revealed the validity of the environmental Kuznets curve (EKC) in all countries. Additionally, the results show that the uncertainty index increases environmental degradation, especially in exceptionally substantial changes in Morocco, Turkey, and Iran. Energy consumption and population across the sample increased CO_2 emissions over the study period. Consequently, policymakers in MENA countries should take into account the economic uncertainty index, especially considering its recent rise, when developing any strategies and plans aimed at improving environmental standards, as well as the need to encourage the use of renewable energy to increase its percentage contribution to the total energy consumption [31].

The literature review establishes that global environmental damage is not only caused by economic variables as previously thought. Several other variables affect environmental damage, such as carbon emissions, population, and lifestyle. However, economic variables also affect these non-economic variables. Therefore, it is important to examine the influence of economic and non-economic variables on the environmental quality index in emerging market countries, using several hypotheses discussed in the following section.

Hypotheses and Research Model Construction: After reviewing several empirical studies, a more complete understanding of the relationship between economic growth and the environment was obtained. This understanding is the basis for constructing the hypotheses and the mathematical models used in this study.

The Influence of Economic Index Growth on the Pollution Index: Economic growth has a complex relationship with pollution indices, where in the initial stages of economic development, increases in industrial activity and energy consumption tend to lead to increases in pollutant emissions. However, the concept of the Environmental Kuznets Curve

(EKC) suggests that after reaching a certain level of income, countries are often able to reduce pollution levels through increased environmental awareness, implementation of stricter regulations, and adoption of clean technologies. Further research also highlights the vital role of effective environmental policies and green technologies in reducing pollution along with economic growth [32, 33].

H1: *Economic growth has a positive (unidirectional) influence on the pollution index.*

Effect of Carbon Emissions on Pollution Index: Carbon emissions, especially in the form of carbon dioxide (CO_2), are a major contributor to global pollution and climate change indices. The main sources of carbon emissions include the burning of fossil fuels such as coal, oil, and natural gas for energy and transportation needs. Increasing CO_2 concentration in the atmosphere not only increases the air pollution index but also contributes to the greenhouse effect, resulting in global warming and climate change. Studies show that countries with high levels of carbon emissions generally have poor air quality, which affects public health and ecosystems [34, 35].

H2: *Carbon emissions have a positive (unidirectional) effect on the pollution index.*

Effect of Greenhouse Gases on Pollution Index: Greenhouse gases (GHGs), such as carbon dioxide (CO_2), methane (CH4), nitrous oxide (N2O), and fluorocarbon gases, play a key role in determining pollution indices, especially through their contribution to climate change and global warming. GHG emissions come from various sources, including the burning of fossil fuels, agricultural activities, industry, and the use of certain chemicals. Increased GHG concentrations in the atmosphere cause the greenhouse effect, which increases global temperatures and negatively impacts air quality. This contributes to an increase in the frequency and intensity of extreme weather phenomena such as heat waves and heavy rainfall, which can exacerbate air pollution through increased secondary emissions such as tropospheric ozone and fine particulate matter. Methane, as a GHG with a much greater global warming potential than CO_2, contributes significantly to changes in air quality and human health. GHGs not only influence the global climate but also influence pollution indices locally and regionally, with major implications for public health and ecosystems [36, 37].

H3: *Greenhouse gas (GHG) emissions have a positive (unidirectional) influence on the pollution index.*

The Influence of Natural Gas Consumption on the Pollution Index: Natural gas, even though considered to be a cleaner energy source than coal and oil, still produces CO_2 and NOx emissions which can increase the pollution index. The use of natural gas is often considered a transition step towards cleaner energy because the emissions produced are generally lower than other conventional energy sources. However, methane leaks during natural gas production and distribution can exacerbate air pollution problems and the greenhouse effect. Therefore, although natural gas consumption can reduce some types of pollution, good management is necessary to minimize overall emissions, including greenhouse gases [37, 38].

H4: *Natural gas consumption has a positive (unidirectional) influence on the pollution index.*

The Influence of Population on the Pollution Index: An increase in population is closely related to an increase in the pollution index because it usually leads to an increase in human activity which has a negative impact on the environment. Population growth triggers an increase in energy consumption, transportation use, waste production, and urbanization, all of which contribute to increased emissions of pollutants such as carbon dioxide (CO_2), nitrogen oxides (NOx), and fine particulate matter. Studies show that areas with high population growth tend to have poorer air quality, especially in urban areas where population concentrations are high, and infrastructure is often unable to keep up with increasing pollution. In addition, these negative impacts are more pronounced in developing countries, where environmental regulations may be less stringent, and waste and emissions management technologies are not yet optimal. Population pressure has also been shown to accelerate environmental degradation and worsen climate change, which in turn exacerbates pollution problems. Therefore, controlling population growth and improving environmental policies and clean technologies are important to reduce the negative impacts on pollution indices [39, 40].

H5: *Population size has a positive (unidirectional) influence on the pollution index*

3. Methodology

3.1. Research Conceptual Framework

This study intended to investigate the influence of economic, ecological, and demographic variables on the pollution index in Emerging Market countries and provide answers to which of the three variables has the greatest influence on the pollution index. These three aspects are interrelated and very closely related to environmental aspects, as depicted in the study's conceptual framework (see Figure 1).

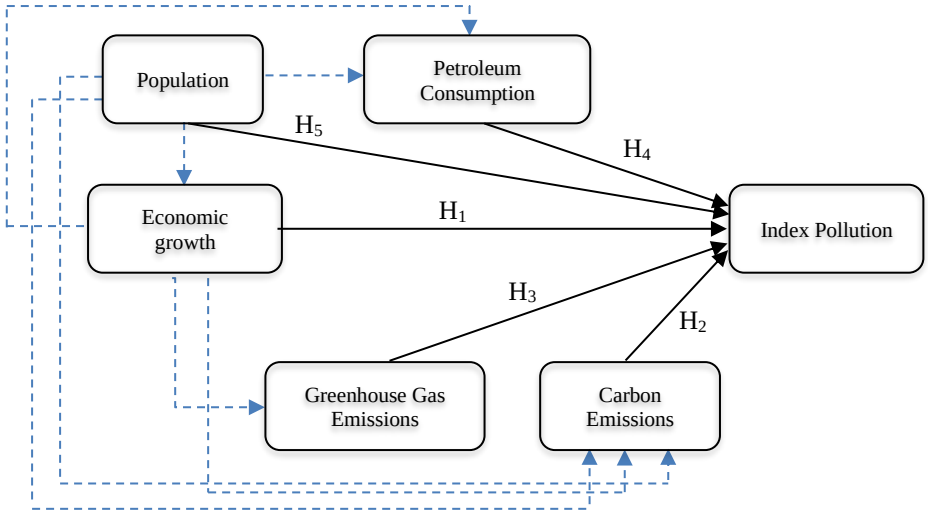

Figure 1. Research Conceptual Framework and Hypothesis Mapping of the Relationship between Independent and Dependent Variables

Figure 1 visualizes the relationship between the economic variables, the ecological variables, and the demographic variables. The conceptual framework encompasses the economic aspect as the independent relationship, represented by economic growth and petroleum gas consumption; the ecological aspect represented by Greenhouse Gas Emissions and Carbon Emissions; and the demographic aspect represented by the population to the dependent variable, which is the pollution index. The straight line shows the relationship between the independent and dependent variables, while the dotted line shows the relationship between the independent variables. The hypothesis of the relationship between the independent and dependent variables theoretically shows a positive or unidirectional relationship, meaning that an increase in the independent variable will have an impact on increasing the pollution index or decreasing environmental quality. The indirect relationships between the independent variables are depicted by the dotted line, suggesting that the hypotheses proposed in this study may not be proven.

3.2. Research Approach

This study used quantitative data to test the relationship between variables in the research model. There are two different opinions regarding the connotation of quantitative research: the first emphasizes the mathematical methods used in quantitative research, and the second emphasizes the focus on numbers or quantities. According to the first opinion, quantitative research is the statistical analysis of observational data, experimental data, and other data and is a general term for a series of mathematical and statistical methods used in testing theoretical hypotheses [41], which emphasizes measuring, calculating, and analyzing the interconnections between entities to explore the essence of the relationship [42]. The second opinion views that any research that presents, explains, and analyzes problems or research objects in terms of their magnitude is quantitative research and that the essence of quantitative research is to use mathematical language, mathematical symbols, and others to describe and explain the problem [43].

3.3. Research Data Objects and Sources

This research used serial panel data from 24 countries based on the MSCI Emerging Market Index for the period between 2013 and 2022. The countries were Nigeria, Turkey, Indonesia, Malaysia, Thailand, Philippines, Ukraine, Pakistan, South Africa, Brazil, Russia, Colombia, Mexico, Chile, Peru, Hungary, Czech Republic, China, Romania, Bulgaria, Poland, South Korea, Croatia, and India. Data was obtained from The Global Economy, Numbeo, The World Population Review, and The World Bank. Static panel data regression was used to see the influence of the independent variable on the dependent variable. The operational definitions and data sources for each variable in the regression model are shown in Table 1.

Table 1. Operational Definition of Variables

Variable	Information	Unit	Source
Economic growth	Total GDP of each Emerging Market country.	Billion ($)	https://data.worldbank.org/
Carbon Emissions	The total amount of CO_2 emissions based on area in the transportation sector is measured in metric tons of CO_2/year/km^2.	CO_2/year/km^2	www.theglobaleconomy.com
Greenhouse Gas Emissions	A form of pollution caused by the presence of several types of gases in the atmosphere which can absorb and retain solar radiation, causing the earth's surface temperature to increase.	Kt/CO_2	www.theglobaleconomy.com
Petroleum Consumption	Consumption of fossil fuels (petroleum).	One Thousand/Barrel	www.theglobaleconomy.com
Population	The entire number of people or residents in an area.	Millions of people	www.worldpopulationreview.com
Pollution Index	A measure used to assess air pollution. Increasing air pollution will increase the air quality index value.	Index	www.numbeo.com

Data on economic growth, carbon emissions, greenhouse gas emissions, gasoline consumption, and population were converted into natural logarithm (Ln) data to allow the parameters to be interpreted as elasticity.

3.4. Model Estimation and Research Model Equations

This study used three estimation models, i.e., Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM). The regression equation in estimating the research model is as follows:

$$Y_{it} = a + \beta_1 X_{1it} + \beta_2 X_{2it} + \beta_3 X_{3it} + \beta_4 X_{4it} + \beta_5 X_{5it} + e_{it} \quad (1)$$

where Yit is Pollution Index (Bound Variable), X_{1it} is Economic growth, X_{2it} is Carbon Emissions, X_{3it} is Greenhouse Gas Emissions, X_{4it} is Petroleum Consumption, X_{5it} is Population, t is Period t, i is Entity i, α is Constant, e is Variable outside the model.

A panel data regression analysis model spanning from 2013 to 2022 was utilized to estimate the influence of Economic growth, Carbon Emissions, Greenhouse Gas Emissions, Petroleum Consumption, and Population on the Pollution Index. Interpretation of panel data regression models has three types of models; Partial Least Square (PLS) Regression, FEM (Fixed Effect Model) and REM (Random Effect Model). To determine the best model, one of the model estimation techniques is the Chow test, Lagrange multiplier test and Hausman test [44].

Before conducting data management, researchers use the log method, this method is used to obtain accurate and significant estimation results. There are two anticipatory reasons why researchers use the log method: First, to normalize data distribution because one of the basic assumptions in the classical regression model is that dependent variables are normally distributed. In practice, data is not always normal. Many economic data are not normally distributed. Second, for interpretation reasons, mathematically, changes in logged data are an approximation of relative changes (in percent) from the initial data (before transformation). Thus, the interpretation of the marginal impact of changes in independent variables on dependent variables becomes more meaningful.

The Hausman test is a further test in selecting a panel data regression model. It aims to determine which model is suitable between FEM and REM. In the Hausman test, a Chi-square probability value will be obtained that is smaller than alpha (α) (0.0000 < 0.05), meaning that FEM is better to use when compared with REM, and vice versa if the Chi-square Probability value is greater than alpha (α) (0.0000 > 0.05), it means that REM is better to use compared to FEM. After determining the best model, the next step was running the Statistical Significance Test via the F test (Concurrent Significance Test).

4. Results and Discussion

4.1. Pollution Index in Developing Countries

Based on pollution index data in emerging market countries in mid-2024 published by Numbeo, as shown in Figure 2, two countries have a worrying pollution index category, i.e., Nigeria and Peru, with an index value amounting to 88.2 and 82.5 respectively in the red category. Meanwhile, there are 3 countries in the slightly lower category, i.e., China, Chile, and Thailand.

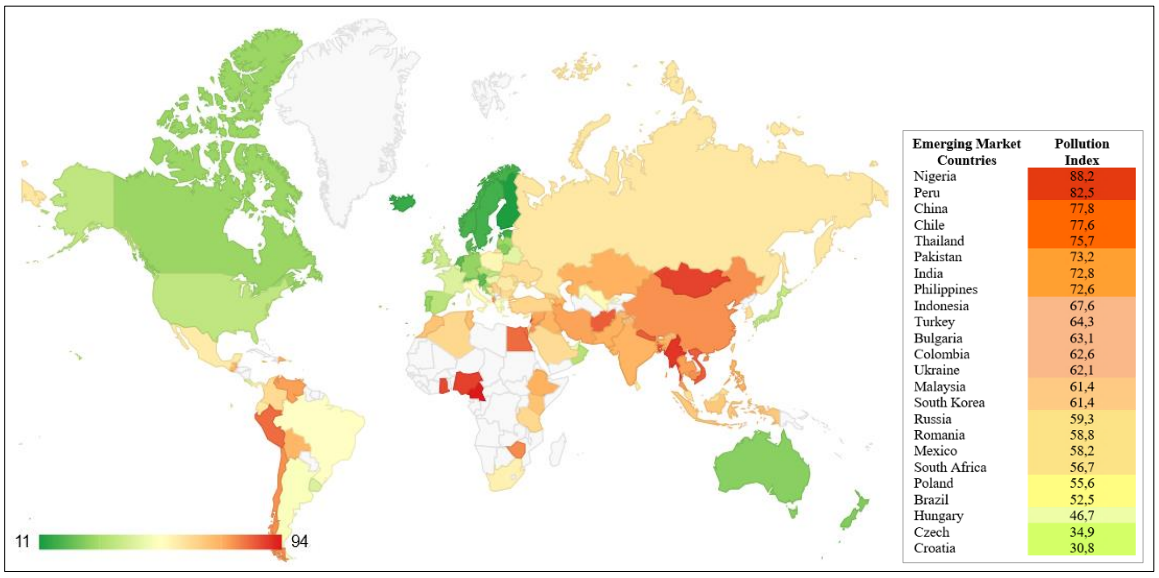

Figure 2. Pollution Index in Emerging Market Countries

(Source: *https://www.numbeo.com/pollution/rankings_by_country.jsp*)

Most Emerging Market countries are classified as above 50 index numbers. Only two countries, Czech Republic and Croatia, have pollution index values below 50, meaning that their pollution level is at a low level and safe. A low pollution index reflects a healthy and quality environment, thus having a positive impact on human health, the economy, and the ecosystem, which implies the effectiveness of environmental policies and sustainable practices implemented by the government and society. Figure 2 suggests that Emerging Market countries generally have pollution problems. A high pollution index can affect many aspects of life and the environment and requires serious attention from the government, industry, and society to reduce its negative impacts. On this basis, this study analyzed the variables that influence the level of pollution index in Emerging Market countries. By looking at the variables that influence the pollution index, governments of these countries could formulate effective policies as anticipatory and preventative steps against severe environmental damage.

4.2. Model Estimation Results

The estimation techniques, i.e., the Common Effect Model (CEM), Fixed Effect Model (FEM), and Random Effect Model (REM), used Natural Logarithmic (Ln) to reduce excessive data fluctuations. In the (Ln) model, several provisions were considered, including that the Ln model coefficients have a simple interpretation, and the Ln model often reduces a common statistical problem, known as heteroscedasticity. Next, testing was carried out to select the best estimation model. The first step taken was performing the Lagrange multiplier (LM) test to select the best model between the CEM or REM models, followed by the Hausman test to select the FEM or REM model.

Table 2. Model Estimation Results- Source: Stata 17, processed

Variable	CEM		FEM		REM	
	t-Statistics	P > | t |	t-Statistics	P > | t |	t-Statistics	P > | t |
LnEconomic Growth X1	-3.04	0.003	-3.06	0.003	-3.02	0.003
LnCarbon Emissions X2	-1.27	0.267	0.21	0.835	-0.15	0.881
LnGreenhouse Gas Emissions X3	0.78	0.438	-0.77	0.444	0.09	0.930
lnX4 Gasoline Fuel Consumption	3.61	0,000	0.80	0.423	0.89	0.376
LnPopulation X5	5.17	0,000	1.10	0.272	2.95	0.003

The results of the Lagrange multiplier test and Hausman test for the three models can be seen in Table 3. The calculation results explain that each model has a different significance value.

Table 3. Lagrange Multiplier Test

CEM, FEM
Prob > F = 0.000

Table 3 shows the results of the limited F test taken from the FEM output results. The probability value F > 0.0000 is smaller than the significance level = 0.05, so H0 (CEM) is rejected, and the best temporary calculation model is the FEM model. Based on these results, it is necessary to carry out the Hausman test to determine the best calculation between the REM and FEM models. The assumptions used in the Hausman test are H0 = REM, while H1 = FEM. The Hausman test results (see Table 4) show a probability value > chi-square = 0.0821; hence, the best model that can be used was the FEM model.

Table 4. Hausman test

FEM, REM
Prob > chi^2 = 0.0821

The classical assumption test revealed evidence of multicollinearity, heteroscedasticity, and autocorrelation. Therefore, it was necessary to improve the model using the generalized least squares (GLS) method to fulfill the classical assumption test in the FEM model. The following are the improvement results in the FEM model, shown in Table 5.

Table 5. F EM-GLS results - Source: Stata 17, processed

FGLS Regression				
Numb. Observations = 240				
Numb. Groups = 24				
Prob > chi^2 = 0.000				
Variable	**Coefficient.**	**Std. Error Std. Err.**	**Q**	**Problem.**
LnEconomic Growth (X1)	0. 0786826	0.0109303	7.20	0,000
LnCarbon Emissions (X2)	0.035536	0.0774877	0.46	0.647
LnGreenhouse Gas Emissions (X3)	-0.2383299	0.0948791	-2.51	0.012
LnGasoline Fuel Consumption (X4)	0.0595302	0.0204973	2.90	0.004
LnPopulation (X5)	0.2309843	0.0291033	7.94	0,000
_counter	8.199529	2.763624	2.97	0.007

After improving the FEM model with the generalized least squares (GLS) method and determining independent variables that do not have a significant influence on the model, the result was the following Equation.

$$Y = 8.199529 + 0.0786826 \times X1 + -0.2383299 \times X3 + 0.0595302 \times X4 + 0.2309843 \times X5 \quad (2)$$

From the results of the panel data regression equation, it can be interpreted: that first, the constant value of 20.35941 indicates the constant value of the pollution index (Y). Assuming that the variables economic growth, carbon emissions, greenhouse gas emissions, gasoline consumption and population are equal to zero or constant, then the pollution index will have a constant value of 8.199529.

For the economic growth variable (X1), a positive coefficient value of 0.0786826 was obtained with a t-table value of 0.000, which is a significant effect. This explains that every increase in economic growth will tend to increase the pollution index in developing countries. The carbon emissions variable (X2) has a positive and insignificant effect with a coefficient value of 0.035536, meaning that if there is an increase in carbon emissions it will tend to increase the pollution index. However, the coefficient of the variable X2 is not included in Equation 2 above because its effect is statistically insignificant.

The estimation results for the greenhouse gas emissions variable (X3) obtained a negative coefficient value of -0.2383299 with a t-table result of 0.012, suggesting a significant effect. This means that any increase in the concentration of greenhouse gas emissions will tend to decrease the pollution index value. Gasoline fuel consumption (X4) obtained a positive coefficient value of 0.0595302 with a t-table value of 0.004, which is a significant effect, indicating that every increase in gasoline consumption will increase the pollution index. The population variable (X5) showed a positive coefficient value of 0.2309843 with a t-table value of 0.000, meaning it has a significant effect, implying that every increase in population will increase the pollution index in developing countries.

4.3. Findings and Discussion

The findings indicate that economic growth has a positive effect on the increase in the pollution index (H1). Studies done in several countries also found that environmental quality is influenced by economic growth. In other words, economic growth has a positive effect on environmental quality [7-9]. Other studies related to the impact of economic growth on environmental quality have also shown that the higher the economic growth, the better the CO_2 emissions on environmental quality because the process of developing a country's economy to improve people's welfare requires natural resource activities. However, some studies have yielded different results; for instance, with increasing economic growth, environmental quality will also increase [10]. These findings are in line with the Environmental Kuznets Curve (EKC) concept, which suggests after reaching a certain level of income, countries are often able to reduce pollution levels through increased environmental awareness, implementation of stricter regulations, and adoption of clean technologies [26, 27]. Meanwhile, the findings of this study confirm that most emerging market countries have not yet reached the peak increase in the pollution index because changes in the economic structure of these countries have not yet reached their peak, considering that changes in the economic structure of a country take a long time [9].

Changes in greenhouse gas emissions should have a negative effect on the pollution index value, but this is not in line with H3, which should have a positive effect. Overall, GHG not only affects the global climate but also affects pollution indices locally and regionally, with major implications for public health and ecosystems [30, 31]. Other studies show that the higher the increase in greenhouse gas emissions, the warmer Earth becomes. Increased greenhouse gas emissions cause an increase in the ability of the earth's atmosphere to retain solar heat and prevent it from leaving the atmosphere. This results in global warming and more extreme climate change, including an increase in global average temperatures, melting ice at the poles, and unstable weather patterns. These findings suggest that the increasing GHG has a significant impact on the lives of humans and other living things and has become a global concern. This is why GHG may have a negative effect on the pollution index value and environmental quality [12].

Increasing gasoline consumption has a positive effect on increasing the pollution index (H4). This finding is in accordance with the hypothesis in this study. Other studies also found that the relationship between CO_2 emissions and energy consumption is very close [13], which implies that these countries have maintained a steady consumption pattern of carbon-intensive fuels. It also implies that additional efforts are needed to find cleaner energy production methods and achieve a more sustainable economy. Hence, the use or consumption of fuel for transportation and industry has negative externalities through three sources: oil consumption, oil production, and the effects of greenhouse gas emissions due to burning fuel oil.

The increasing population has a positive effect on the increasing pollution index (H5). This finding is in line with the research results by Sasana and Aminata [45], suggesting that an increase in population will increase the level of CO_2 emissions, and as the population of a country increases, so does energy consumption per capita, which tends to cause excessive air pollution. If the air pollution is not absorbed in the soil, it will endanger the environment and the health of living things. Likewise, this finding is supported by the theory regarding the relationship between population and environmental degradation [46]. The theory states that as the population increases, land is no longer able to provide agricultural products to meet the food needs of the growing population. The carrying capacity of the land as one of the components of the environment will decrease and subsequently result in high levels of pollution due to the use of fuels, especially those that produce greenhouse gas emissions.

This study revealed that the most dominant variables for changes in the pollution index in emerging market countries are population variables and greenhouse gas emissions. It also found that ecological and demographic variables have a more dominant influence on changes in the pollution index compared to economic variables of economic growth and gasoline consumption. In this regard, policies on environmental issues should be more focused on how to raise public awareness regarding environmental issues. Currently, campaigns on air pollution continue to be intensified to increase public awareness of this type of pollution, encourage people to change their lifestyles, and promote innovation in renewable energy while boosting human life quality, which is measured by the Human Development Index (HDI). In various countries, although the population continues to increase, an increase in the HDI could encourage innovation and awareness of environmental damage [47, 48].

Significant results occur at quantiles 0.1 to 0.7, indicating that the impact is greater at the low-middle quantiles, where most of the sample distribution is found. The HDI captures the development of human capabilities related to health, education, and quality of life. The negative correlation between HDI and EQ suggests that as people in developing Asian countries gain access to better health systems, they have more opportunities to become more knowledgeable, and as they improve their living standards, this will reduce CO_2 emissions from environmental degradation. These results suggest that investment in human development in Asia has a positive effect on environmental quality. Regarding the IPM-CO_2 relationship, this study validates policies to support human development in developing countries in Asia because their policies could have an impact on environmental quality. Previous studies that have used HDI or other sub-components, such as education in APEC, found that higher levels of HDI or sub-components help reduce emissions. In China, increasing human capital (e.g., education) reduced CO_2 emissions, but in other studies from West African countries or Pakistan, increasing human capital results in higher emissions.

5. Conclusions

Based on the results of the data analysis, it can be concluded that: (a) the variables of economic growth, greenhouse gases, gasoline consumption, and population have an influence on the pollution index, while carbon emissions do not significantly affect the Pollution Index in Emerging Market countries; (b) the variables that have the greatest influence on the pollution index in emerging market countries are ecological and demographic variables compared to economic variables.

5.1. Theoretical Contributions

The findings suggest that the cause of environmental degradation is not only due to economic growth variables. Ecological and demographic variables also play a role in causing environmental degradation. The conceptual framework explains that economic variables respond to changes in demographic variables. Population growth will result in increasing consumption, which is often met with an increase in the amount of production, both goods and services. This economic activity is the factor that triggers issues or disruptions in human interactions with other living things and the surrounding environment, thus causing ecological problems or environmental degradation. However, improving the quality of the economy and education can increase public awareness of the impact of environmental damage. This would eventually improve how humans interact with living things and the surrounding environment. This is what Kuznet explained theoretically through the Environmental Kuznets Curve (EKC). Economic growth has a negative impact on the environment in the initial stages but a positive impact in the long term. Theoretically, this study offers a clearer understanding of the flow of thought behind the Environmental Kuznets Curve (EKC) theory.

5.2. Practical Implications

The research findings, in addition to providing theoretical contributions, provide policy implications for addressing environmental issues. The following are several policy implications based on the findings of this research: (a) Population growth must be balanced with ecological understanding, both through formal and informal education. The government needs to provide information to the public about maintaining environmental quality. Environmental-based education must be accessible to the public. One effort that can be made is to include environmental-based education in the formal education curriculum; (b) The inevitable increase in the number of vehicles must be balanced with the development of environmentally friendly combustion technology so that it can reduce fuel consumption and carbon emissions; (c) Economic growth should be directed towards sustainable economic development, which not only prioritizes economic sustainability but also emphasizes social sustainability and the preservation of the surrounding natural environment.

5.3. Research Limitations and Future Research Recommendations

Despite obtaining new findings and evidence related to the understanding of the Environmental Kuznets Curve (EKC) concept and proposing guiding policies related to environmental issues in Emerging Market countries, this study still contains certain limitations that provide direction for further research. First, population data in this study was not sorted by age group and included all residents starting from 0 years. Further research should include populations aged 7 years and over to represent the people who interact with the environment. Second, the model used was still linear. Future studies should consider using non-linear models that incorporate the Environmental Kuznets Curve (EKC) theory.

6. Declarations

6.1. Author Contributions

Conceptualization, S.S., A.S.R., F.U.S., and M.S.W.; methodology, S.S. and A.S.R.; software, A.S.R. and F.U.S.; validation, S.S., A.S.R., and F.U.S.; formal analysis, S.S., A.S.R., F.U.S., and M.S.W.; investigation, S.S., A.S.R., F.U.S., and M.S.W.; resources, A.S.R. and F.U.S.; data curation, A.S.R. and F.U.S.; writing—preparation of the original draft, S.S., A.S.R., F.U.S., and M.S.W.; writing—review and editing, S.S. and M.S.W.; visualization, M.S.W.; supervision, S.S.; project administration, S.S.; funding acquisition, S.S. All authors have read and approved the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available upon request from the corresponding author.

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6.4. Institutional Review Board Statement

Not applicable.

6.5. Informed Consent Statement

Not applicable.

6.6. Declaration of Competing Interest

The authors declare that there is no conflict of interests regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, informed consent, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been completely observed by the authors.

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