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REVIEW ARTICLE

EXPLORING THE ENVIRONMENTAL KUZNETS CURVE (EKC) AND THE IMPACT OF ENVIRONMENTAL DEGRADATION ON HEALTH IN SELECTED DEVELOPING COUNTRIES

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ABSTRACT

This study explains the relationship between the emission of greenhouse gases like CO_2, CH_4, and N_2O with GDP per capita, fossil fuel energy consumption, foreign direct investment, and population density following the framework of the Environmental Kuznets Curve(EKC) hypothesis.The impact of the Environmental Degradation Index, Foreign Direct Investment and Population Density on Health Index is also explained in this study. To explain these relationships both the Fixed Effect Model and the Random Effect Model are used. For this purpose, the study employs panel data regression based on several countries selected out of three continents: Asia, Africa, and America.The panel data regression confirms the existence of EKC for all the greenhouse gases emitted. Further, the health outcome is significantly explained by the relevant explanatory variables. Again a decomposition model based on Kaya Identity is also used to describe the fossil fuel intensity of GDP.This study also considers some policy suggestions to improve the environment's quality by reducing environmental degradation.

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INTRODUCTION

Currently, the uncontrolled progress of an economy can hardly be separated from the consumption of non-renewable energy sources. However, the greater dependence on non-renewable energy sources for the growth of the economy led to two types of adverse situations. Firstly, the continuous use of these non-renewable sources of energy has led to environmental pollution leading to global warming. Secondly, the excessive use of fossil fuels leads to the depletion of its stock with a concomitant rise in its user cost thus severely depriving the future generations of its use. Non-renewable energy sources like coal are available at a cheaper rate than renewable energy sources which involves some infrastructural costs. As a result of this, consumers with low incomes prefer non-renewable energy sources to renewable energy sources even if the latter emits less pollution and save energy. However, consumers with high incomes usually prefer renewable energy sources and make use of some energy-efficient technologies. But low/middle-income countries usually use more non-renewable resources which have degrading effects on the environment. This degradation in the quality of the environment has a negative impact on certain health indicators like Maternal Survivability Rate, Infant Survivability Rate and Life Expectancy at Birth. In order to explain the interconnectedness between economic development and environmental sustainability, Sachs (2015) argued that the emission of greenhouse gases results in climatic changes, worsening of poverty and disproportionately affects the infant groups. Dasgupta (2013) focused on welfare economics and intergenerational equity and emphasized the ethical implications of greenhouse gas emissions for future generations by arguing that the health impacts of climate change including infant mortality should be a key consideration in policy-making. Greenstone (2017) indicates that exposure to pollutants like ($PM_{2.5}$) can lead to respiratory and cardiovascular diseases, increasing maternal mortality risks. Nordhaus (2020) also stated in his paper that rising temperatures and extreme weather events driven by greenhouse gas emissions can limit access to maternal health services. It was also argued that climate change can directly and indirectly affect health, reducing life expectancy (Sen *et al*., 2024). The negative impact of air pollution on life expectancy was demonstrated by the increased level of a common pollutant ($PM_{2.5}$) from the emission of greenhouse gases which reduced the life expectancy at birth, particularly in China (Ebenstein *et al*., 2015). These studies suggest that the health impact of greenhouse gas emissions needs to be considered with due importance.

It has been found that global warming can be reduced if four of the greenhouse gases viz. CO_2, CH_4, N_2O, and SF_6 can be controlled.It is found that the atmosphere's methane and nitrous oxide levels increase due to human activities. The production of fossil fuels such as the processing of natural gas and mining of coal, livestock farming, etc raises the level of methane in the atmosphere. According to a study in 2022 by the scientists of NASA(National Aeronautics and Space Administration) and NOAA (National Oceanic and Atmospheric generated Administration),it was suggested that from 2006 to 2016, 85% of the methane emissions increased due to microbial emissions by livestock, agriculture, etc. The main sources of nitrous oxide emission into the atmosphere are burning fossil fuels and using nitrogen-containing fertilizers. During the two years 2020 and 2021, the emission of nitrous oxide was maximum. However, fossil fuel is considered the main culprit that leads to the emission of greenhouse gases thus adversely affecting the health of the people. So in this context, it is also considered pertinent to explain the variation of fossil fuel use as a proportion of GDP by developing a decomposition model based on Kaya Identity.

The Environmental Kuznets Curve (EKC) is an economic theory suggesting that environmental degradation increases in the early stages of economic development, due to higher levels of industrialization, increased consumption of resources, and pollution but decreases after a certain threshold income level is reached due to factors such as improved technology, increased environmental awareness, and the implementation of effective environmental policies, leading to an inverted U-shaped curve. In the case of developing countries, the validity of the EKC hypothesis might encourage sustainable future development as the level of the greenhouse gases emission decreases beyond a certain threshold level due to the economic growth which is facilitated by the high rise in the level of income (Wang *et al*., 2016). Apart from this income level, there are certain other factors like urbanization, fossil fuel energy consumption, FDI, etc. which may have impacts on the shape of the EKC. In their study, Grossman and Krueger (1991) stated that urbanization initially increases pollution due to industrial activities but can later lead to reduced emissions with economic growth. Again FDI can lead to environmental degradation in host countries with lax regulations, as firms relocate to avoid stricter environmental laws in their home countries (Copeland and Taylor, 1994). In their study, Grossman and Krueger(1991) suggested that fossil fuel consumption increases pollution in the early stages of economic growth leading to the increased emission of greenhouse gases.

According to Lopez (1992), the absolute level of pollution may increase even with the increased use of more modern and efficient technologies, and technology's effect on pollution may be ambiguous. In this backdrop it seems imperative to focus on the main objectives of this study as follows:

- To find out the impact of GDP per capita, fossil fuel energy consumption (FFEC), foreign direct investment (FDI), and population density (PD) on the emission of various greenhouse gases like CO_2, CH_4, and N_2O for the set of 36 developing countries, selected 12 each from the three continents- Asia, Africa, and America.
- To set up a fossil fuel decomposition model based on Kaya identity.
- To determine the impact of the Environmental Degradation Index (EDI), Population Density, and Foreign Direct Investment on maternal and child health-related outcomes.
- To build up some policy suggestions that would improve the environment’s quality by reducing environmental degradation.

LITERATURE REVIEW

Economists have varied views on exploring the Environmental Kuznets Curve (EKC) contributing to a rich and nuanced discourse. Some economists argue that the EKC supports the idea that economic growth can lead to environmental improvement. They emphasize the role of technological progress and policy interventions in decoupling economic development from environmental degradation. Economists acknowledge that the EKC relationship may vary across countries and sectors. Factors such as income distribution, initial environmental conditions, and sector-specific characteristics influence the dynamics of the EKC. Researchers strive to uncover these nuances for a more accurate understanding. Several economists have contributed to the discourse on the Environmental Kuznets Curve (EKC) over the years. There are also several studies relating to how environmental degradation leads to deterioration in health outcomes or improvement in its quality triggers betterment in health. Further, there are studies pertaining to decomposition based on Kaya Identity.

Literature regarding Environmental Kuznets Curve (EKC): Adams and Acheampong (2019) tried to determine the impact of democracy and renewable energy on carbon emissions by using unbalanced data related to 46 sub-Saharan African countries over the period 1980-2015. Apart from this, Foreign Direct Investment, trade openness, population, and economic growth were considered to be the factors that caused the emission of carbon in those regions. It was also observed that when democracy was present, the intensity of carbon emissions decreased due to economic growth. So, no evidence of EKC was found. Al Mulali et al. (2016) examined the existence of the EKC hypothesis in Vietnam over the period 1981-2011. The results suggest that pollution is justified since capital, energy-intensive imports, and fossil fuels are found to increase the level of pollution significantly but exports have no significant effect on pollution. The results also suggested that the labour force lessens pollution in Vietnam as most of the labor force in Vietnam is employed in less energy-intensive agricultural and service sectors.

Anastacio (2018) in his work found evidence of U-shaped EKC for CH_4 emission in the case of Argentina. From the work of Aye and Edoja (2017), it was found that in the case of developing countries, the increased emission of CO_2 decreased economic growth and vice-versa or in other words the emission of CO_2 had a negative impact on economic growth for the case of developing countries but for the case of developed countries the CO_2 emission had a positive impact on economic growth. Dasgupta *et al.* (2002) explored the role of institutions in shaping the EKC relationship highlighting the significance of governance structures in environmental management. Grossman *et al*. (1991) conducted pioneering work on the EKC, introducing the concept that environmental degradation initially worsens but eventually improves with economic development.

Grossman *et al*.(1995) built on their earlier work and refined the EKC hypothesis acknowledging the importance of policy interventions and technological advancements in influencing environmental outcomes. Jalil *et al*. (2009) examined the long-run relationship between carbon emissions and energy consumption, income, and foreign trade in the case of China by using time series data from 1975-2005. The main focus was on testing the existence of an EKC relationship between the emission of $CO_2$and per capita real GDP in the long term. In the long run, income and energy consumption had a major impact on CO_2emissions. Kaika *et al*. (2012) in their study pointed out some controversial aspects based on the EKC hypothesis. There exists a great debate on the fact that there emerges a pollution-free environment with the rise in income. It is often taken for a high positive income elasticity of demand. Mandal *et al*. (2010) studied the existence of the relationship between energy consumption and the growth of output of the Indian cement industry over the period 1979-1980 to 2004-2005. A positive long-run cointegrated relationship was found between output and energy consumption. They also found a long-run bidirectional relationship between energy consumption and growth of output in the Indian cement industry which implies that an increase in energy consumption directly affects the sector's growth and that growth further raises the energy consumption.

Perman *et al*. (2003) provided insights into the methodological challenges of estimating the EKC and emphasized the need for careful consideration of data and model specifications. Seldon *et al*. (1994) extended the EKC framework by incorporating structural variables and further explored the relationship dynamics. Stern (1998) pointed out the importance of the inverted U-relationship corresponding to air pollutants and SO_2 in his paper. In an allied work, Stern et. al. (1998) used fixed and random effect models with both country and time effects. Both dependent (emission per capita) and independent (PPP GDP per capita) variables were considered in natural logarithms. The result showed that when EKC was estimated using data only for OECD countries, the turning point was much lower than when EKC was estimated using data for the world as a whole. Zambrano-Monserrate and Fernandez (2017) analyzed the relationship between N_2O emissions, economic growth, agricultural land used, and exports in Germany by using the Time Series data over the period 1970-2012. It was observed that agricultural land area influenced N_2O emissions positively whereas exports harmed such emissions.

Literature regarding the Impact of Environmental Degradation on Health: Amartya Sen (2004) emphasized the role of environmental quality as a crucial factor in enabling people to lead lives they have reason to value. He also linked environmental sustainability to broader concepts of freedom and capability, highlighting how poor environmental conditions can limit people's well-being as well as opportunities. Banerjee *et al*. (2011) in their paper included the aspects of health and sanitation improvements as part of broader microfinance initiatives. Their findings highlighted that access to better sanitation and clean water through microfinance programs can lead to better health outcomes. Goldin *et al*. (2009) explored historical data to understand the relationship between the quality of the environment and health. Their research indicated that environmental improvements, such as clean water and air, have historically led to significant reductions in infant and maternal mortality rates and increased life expectancy at birth. Mumtaz *et al*. (2022) investigated the influence of exposure to ambient and household particulate matter pollution ($PM_{2.5}$), and ground-level ozone (O_3) pollution on respiratory and cardiac mortality in Pakistan. Wilkinson (1996), in his paper, pointed out that income inequality has an adverse impact on health as a low ranking in the social hierarchy produces negative emotions such as shame, distrust, etc. that lead to worse health conditions via stress-induced behaviours such as smoking, excessive drinking, taking dangerous drugs, and other risky activities.

Literature regarding the Decomposition Model based on Kaya Identity: Ang (2004), in his research on the Logarithmic Mean Divisia Index (LMDI), provided a robust method for decomposing energy consumption and emissions changes. This method helped to identify the contributions of activity, structure and intensity effects on energy use and emission of greenhouse gases. In his paper, Kaya (1990) found that an identity and the IPAT equation(Impact= Population * Affluence * Technology) are foundational frameworks used to decompose the factors contributing to greenhouse gas emissions. These models highlight how population growth, GDP per capita, energy use per unit of GDP and greenhouse gas emissions per unit of energy consumed collectively affect the emission of greenhouse gases.

Ma et. al. (2008) in their paper applied decomposition analysis to Chinese data and found that changes in the industrial structure and energy intensity played a significant role in reducing greenhouse gas emissions despite the ongoing economic growth. Nordhaus (2008) in his paper used Kaya Identity to model the impact of economic growth on emissions and support the carbon pricing mechanism to shift the Environmental Kuznets Curve downwards thereby reducing emissions without hindering economic development. Stern (2004) in his paper conducted an empirical analysis that incorporated the Kaya Identity into EKC models and he found that technological progress and structural changes in the economy were critical for achieving the EKC turning point where the emission of greenhouse gases starts declining. Torres *et al*. (2021) refined and expanded the Kaya Identity framework to develop a more comprehensive emissions indicator pyramid which aimed to provide a multi-layered understanding of the factors influencing greenhouse gas emissions integrating various socio-economic, technological, and policy dimensions. The paper sought to enhance the analytical tools available for assessing and managing emissions, ultimately supporting the development of more effective strategies for achieving sustainable development and mitigating climate change.

Data Source and Key Variables: The present study is based on the secondary data which has been collected from the World Bank data source. This source provides a wide variety of data on GDP, fossil fuel energy consumption, foreign direct investment inflows, population density, and the emission of certain greenhouse gases like CO_2, CH_4, and N_2O during the period 2000-2020. All the selected 36 developing countries have been categorized based on the continents like Asia, Africa, and America.

The key variables are as follows

Fossil fuel energy consumption: Fossil fuel energy consumption leads to a rise in the emission of greenhouse gases. About 75-80% of the emission of greenhouse gases arises from the burning of fossil fuels out of which 90% of the emission constitutes CO_2. Besides CO_2, fossil fuel energy consumption also increases the emission level of CH_4 and N_2O which are discussed below.

CO_2 emission: CO_2 is one of the greenhouse gases which is the greatest contributor to polluting the atmosphere. The primary source of CO_2 emissions is from burning fossil fuels, deforestation, production of heat and electricity, transportation, etc.

N_2O emission: Combustion of fossil fuels for industrial production, soils under natural vegetation, treatment of wastewater, etc. are the major sources of N_2O emission.

CH_4 emission: The major sources of CH_4 emission include fossil fuel use such as the use of oil and natural gas, livestock emission, production of rice due to anaerobic decomposition in flooded rice paddies, fossil fuel exploration and transport, decomposition of organic waste in landfills, etc.

GDP per capita: There is a positive correlation between GDP per capita and the emission of greenhouse gases. As countries experience economic growth the emission of greenhouse gases increases because the economic development involves urbanization, industrialization, etc. which leads to the emission of greenhouse gases to a greater extent.

FDI: Foreign Direct Investment usually leads to the higher growth of the economy. FDI can be both advantageous as well as disadvantageous for an economy. On one hand, FDI can boost economic growth by creating new job opportunities leading to reduced unemployment rates. On the other hand, large FDI inflows can impact the exchange rates, benefiting one country while affecting other countries adversely.

Population density: It is used as one of the independent variables in our study. The higher population density in urban areas often leads to more efficient use of land and reduces dependence on private vehicles which lowers the emission of greenhouse gases. Again, on the other hand, higher population density implies greater combustion of fossil fuels which may increase the emission of greenhouse gases.

Model Specification and Methodology

To examine the concept of the existence of the EKC across the different sets of 36 countries which are classified based on continents like Asia, Africa, and America we make use of the panel data regression. We have selected this set of 36 developing countries because of their moderately high population size and consistently available set of data. In estimating the panel data regression, we have focused on the fixed and random effect models.

Table 1. List of selected countries based on different continents

Asia	Africa	America
United Arab Emirates	Cameroon	Argentina
Bangladesh	Ghana	Bolivia
India	Gambia	Chile
Iran	Kenya	Colombia
Cambodia	Liberia	Peru
Srilanka	Morocco	Venezuela
Myanmar	Madagascar	Paraguay
Nepal	Mozambique	Uruguay
Pakistan	Niger	Brazil
Philippines	Nigeria	Eucador
Thailand	Tanzania	Mexico
Indonesia	Zambia	Honduras
Author's selection based on World Bank data source.		

Due to the relatively smaller time series data, there exists a possibility of the inverse U-shaped relationship between income level and environmental degradation. Thus the pollution model is specified as:

$$P_{i,t}= \alpha_i+ \beta_1 GDPPC_{i,t} + \beta_2 GDPPC_{i,t}^2+ \beta_3 FFEC_{i,t} + \beta_4 FDI_{i,t} + \beta_5 PD_{i,t} + \varepsilon_{i,t} \quad (1)$$

where the subscript i indicates the countries, t indicates the period from 2000 to 2020, P indicates the pollutant type (CO_2, CH_4 and N_2O), GDPPC indicates the GDP per capita, FFEC indicates the Fossil fuel energy consumption, FDI indicates Foreign Direct Investment, PD indicates population density, α_i indicates the intercept and β_i indicates the slope of the coefficients of the corresponding variables.

If β_1=0 and β_2 =0, there exists no relationship between economic growth and the type of pollutants and as a result, we get a horizontal-shaped curve as shown in graph (a) in Fig.1.

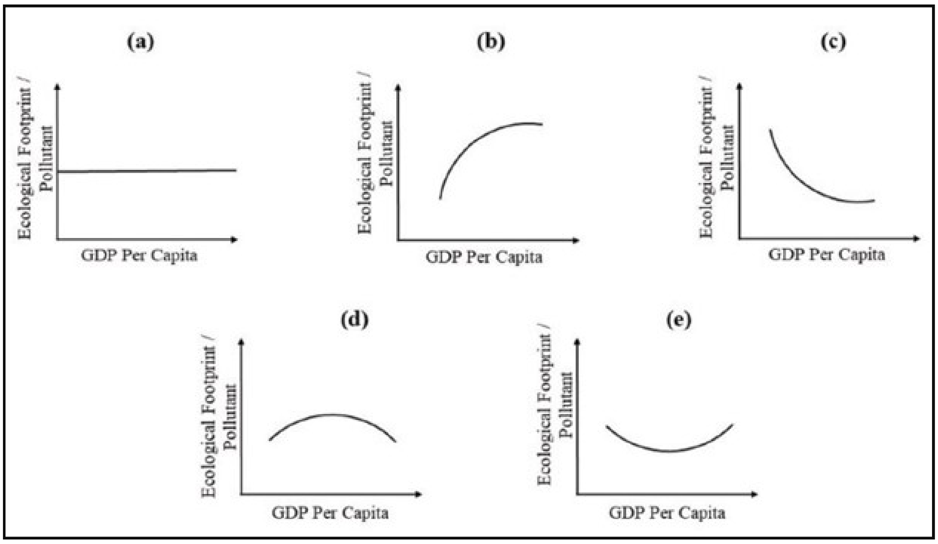

Fig. 1. Graphs showing the relationship between Environmental Degradation and GDP per capita

If $\beta_1>0$ and $\beta_2=0$, then we obtain a monotonically increasing relationship between economic growth and the type of pollutants which is expressed in graph (b) in Fig.1.

If $\beta_1<0$ and $\beta_2=0$, then it is found that with a rise in GDP, the environmental degradation decreases monotonically. This is shown in graph (c) in Fig.1.

If $\beta_1>0$ and $\beta_2<0$, then it is seen that at the initial stage the environmental degradation increases with the increase in the level of income but as soon as the threshold level of income is reached the environmental degradation falls. Thus an inverted U-shaped EKC is obtained as shown in graph (d) in Fig.1.

If $\beta_1<0$ and $\beta_2>0$, it is observed that in the initial years, with an increase in GDP, the environmental degradation falls and after a certain time point the pollution rises, which is an unusual case. Thus, we obtain a U-shaped curve as shown in graph (e) in Fig.1.

For each cross-sectional unit instead of treating the intercept term α_i as fixed, we consider it as a random variable with mean α, and the intercept term for each unit is written as $\alpha_i = \alpha + \varepsilon_i$ where ε_i is the random error term with 0 mean and variance σ_ε^2. Thus, substituting in the original model (1) we get

$$P_{i,t}= \alpha+ \beta_1 GDPPC_{i,t} + \beta_2 GDPPC_{i,t}^2 + \beta_3 FFEC_{i,t} + \beta_4 FDI_{i,t} + \beta_5 PD_{i,t} + \varepsilon_i + U_{i,t}$$

$$P_{i,t}= \alpha+ \beta_1 GDPPC_{i,t} + \beta_2 GDPPC_{i,t}^2 + \beta_3 FFEC_{i,t} + \beta_4 FDI_{i,t} + \beta_5 PD_{i,t} + w_{i,t} \quad (2)$$

where $w_{i,t} = \varepsilon_i + U_{i,t}$; which is the composite error term and it consists of two components, ε_i which is the country-specific error component and $U_{i,t}$ which is the combined time series and cross-section error component. The assumptions that can be made for this model are as follows:

$\varepsilon_i \sim N(0,\sigma_\varepsilon^2)$
$U_{i,t} \sim N(0,\sigma_u^2)$
$E(\varepsilon_i U_{i,t}) = 0$
$E(\varepsilon_i \varepsilon_j)=0 \ (i\neq j)$
$E(U_{i,t}U_{i,s}) = E(U_{i,t}U_{j,t}) = E(U_{i,t}U_{j,s}) = 0 \ (i\neq j;\ t\neq s)$

Thus, it is found that the individual error components are uncorrelated with each other and also across both the cross-section and time series data. The choice between the Fixed Effect Model and the Random Effect Model is made based on the assumption of whether there exists a correlation between ε_i and Y regressors. The Random Effect Model is to be chosen if there exists no correlation between ε_i and Y's while if there exists a correlation between ε_i and Y's, then the Fixed Effect Model is to be chosen. The Hausman test is also used to choose between the Fixed and Random Effect Models. The value of the corresponding test statistic follows an asymptotic chi-square distribution. If the null hypothesis gets rejected then the Fixed Effect Model is considered to be appropriate otherwise Random Effect Model is to be chosen.

We also consider some health and environment-related variables proxied by Health Index (HI) and Environmental Performance Index (EPI). These indices need to be constructed by using the UNDP goalpost method and are shown below.

The purpose of constructing the Health Index (HI) is to focus on positive aspects of human health based on some relevant components. It plays an important role in the process of development. The negative aspects of health are suitably transformed into a positive index based on the goalpost method. We take into consideration the various aspects of health namely- Infant Mortality

Rate (IMR), Maternal Mortality Rate (MMR), and Life Expectancy at Birth (LE) for the selected countries to accomplish the analysis.

Infant Mortality Rate (IMR): It is a health indicator that measures the number of deaths of infants under one year of age per 1000 live births within a given period, typically one year. It is a negative indicator. It is expressed as

IMR=(No. of Resident Infant Deaths/ No. of Resident Live Births) *1000

Maternal Mortality Rate (MMR): It is a public health indicator that measures the number of maternal deaths per 100000 live births within a specific period, typically one year. It is a negative indicator. It is expressed as

MMR= (No. of Resident Maternal Deaths/ No. of Resident Live Births) *1000

Life Expectancy at Birth (LE): It is a statistical measure used to estimate the average number of years a newborn is expected to live, assuming the current mortality rates to be constant at the time of birth. It is a positive indicator.

We convert the Infant Mortality Rate and Maternal Mortality Rate into positive indices and term them as Infant Survivability Index and Maternal Survivability Index respectively. To construct the Infant Survivability Index, Maternal Survivability Index, and Life Expectancy at Birth Index we take the help of the Goalpost method.

Infant Survivability Index (ISI)= $\frac{Maximum\ Value\ of\ IMR - Actua\ \ Value\ of\ IMR}{Maximum\ Value\ of\ IMR - Minimu\ \ \ Value\ of\ IMR}$

where IMR is the Infant Mortality Rate

Maternal Survivability Index (MSI)= $\frac{Maximum\ Value\ of\ MMR - Actua\ \ Value\ of\ MMR}{Maximum\ Value\ of\ MMR - Minimum\ Value\ of\ MMR}$

Where MMR is the Maternal Mortality Rate.

Life Expectancy at Birth Index (LEI)= $\frac{Actual\ Value\ of\ LE - Minimum\ Value\ of\ LE}{Maximum\ Value\ of\ LE - Minimu\ \ \ Value\ of\ LE}$

The Health Quality Index (HI) is considered simply an average of the above three indices

Health Quality Index (HI)= (ISI+MSI+LEI)/3

All these indices are assumed to contribute positively to health quality.

To quantify and mark the performance of the environment numerically based on the country's policies we take the aid of an index known as the Environmental Performance Index(EPI). The EPI ranks countries based on 40 performance indicators across certain issues- namely air quality, water quality, heavy metals, biodiversity, forests, fisheries, climate and energy, air pollution, water resources, and agriculture covering environmental health and ecosystem vitality. The indicators provide a measure at the national level of how close the countries are to establishing environmental policy goals. We construct a negative version of this EPI and term it as Environmental Degradation Index (EDI) to show its impact on health outcomes. The EPI is converted in a negative sense to yield EDI by using a suitable goalpost method.

EDI = $\frac{Maximum\ value\ of\ EPI - Actua\ \ value\ of\ EPI}{Maximum\ value\ of\ EPI - Minimum\ value\ of\ EPI}$

Here we also try to find out the impact of the Environmental Degradation Index (EDI), Foreign Direct Investment(FDI), and Population Density(PD) on the Health Index(HI). This is to be done by fitting a panel regression where HI is considered the dependent variable and EDI, FDI, and PD are considered the independent variables.

Table 2. Expected Sign of EDI, FDI, and PD on Health Index (HI)

Independent Variables	Expected Sign on Health Index(HI)	
EDI	Negative	
FDI	Positive	Negative
PD	Positive	Negative

We fit the panel regression model on the set of developing countries categorized on a continental basis- Asia, Africa, and America as mentioned before. Out of the 36 countries considered earlier,12 countries have been excluded namely- the United Arab Emirates(UAE), Pakistan, Thailand, Indonesia, Cameroon, Liberia, Zambia, Peru, Venezuela, Brazil, Mexico, and Honduras due to the non-availability of proper data sets.

The panel regression model is given by:

$$HI_{i,t} = \lambda_i + \gamma_1 EDI_{i,t} + \gamma_2 FDI_{i,t} + \gamma_3 PDI_{i,t} + \varepsilon_{i,t} \quad (3)$$

Where λ_i indicates the intercept and γ_i indicates the slope of the coefficients of the corresponding variables. This model is to be fitted based on 24 countries.

Elasticity Approach Based on EKC

To understand the fossil fuel intensity of GDP, it is relevant to build up a decomposition framework by applying the notion of Kaya identity. Further, an analysis of the variation of elasticity of fossil fuel with respect to GDP is carried out by using the decomposition method. Thus we may consider

$$\frac{Fossil\ Fuel}{GDP} = \frac{Fossil\ Fuel}{Energy} * \frac{Energy}{FDI} * \frac{FDI}{Industrial\ Production} * \frac{Industrial\ Production}{GDP}$$

Taking log on both sides,

$$\log(FF/Y_D) = \log(FF/E) + \log(E/FDI) + \log(FDI/IP) + \log(IP/Y_D)$$

Taking first difference,

$$\Delta\log(FF/Y_D) = \Delta\log(FF/E) + \Delta\log(E/FDI) + \Delta\log(FDI/IP) + \Delta\log(IP/Y_D)$$

Or,

$$\frac{\Delta \log\frac{FF}{YD}}{\Delta\log YD} = \frac{\Delta \log\frac{FF}{E}}{\Delta\log YD} + \frac{\Delta \log\frac{E}{FDI}}{\Delta\log YD} + \frac{\Delta \log\frac{FDI}{IP}}{\Delta\log YD} + \frac{\Delta \log\frac{IP}{YD}}{\Delta\log YD}$$

Or,

$$\varepsilon_{FFIYD} = \varepsilon_{FFE} + \varepsilon_{EFDI} + \varepsilon_{FDIIP} + \varepsilon_{IPYD}$$

where,

FF/Y_D = Fossil Fuel intensity of Gross Domestic Product(GDP).
FF/E = Fossil Fuel intensity of Total Energy use.
E/FDI = Energy intensity of Foreign Direct Investment.
FDI/IP = Foreign Direct Investment intensity of Industrial Production.
IP/Y_D = Industrial production intensity of Gross Domestic Product(GDP).

As the use of fossil fuel is influenced by the scale of production of GDP and the impetus to such output growth is derived from the imperative of enhancing people's well-being, it seems important to focus on factors that directly or indirectly contribute to the fossil fuel intensity of GDP and attendant notion of elasticity of net intensity with respect to output. In this perspective, we take into account some concepts including fossil fuel intensity of total energy use, energy use per unit of FDI, scale of FDI per unit of industrial production, and industrial production as a ratio to GDP.

The key ratios and their specific elasticities need to be elaborated in this context. Here $\frac{FF}{YD}$ indicates the intensity of fossil fuel use per unit of GDP and it indirectly alludes to the potential to contribute towards environmental pollution through the emission of toxic gases like CO_2, N_2O, and CH_4. As fossil fuel is a recognized input towards furthering the growth in the three major spheres of an economy, a substantial volume of gases is likely to emerge from the GDP production sphere. With the decreased use of fossil fuel per unit of GDP, the environment is likely to function in a better and more efficient manner. $\frac{FF}{E}$ refers to the proportion of fossil fuel in total energy consumption which envelopes both non-renewable and renewable sources of energy with expansion of GDP, requiring an increasing amount of energy use and relatively high cost towards the process of renewable energy transition, fossil fuel consumption in energy is likely to rise triggering greater environmental pollution in the form of emission of GHGs. Generally, it is often held that FDI may lead to technology transfer, better innovation processes and more scientific skills tend to develop renewable energy. But contrary to this claim, there is the view that FDI may be an avenue of outsourcing dirty industries to developing economies, which with fragile environmental regulations are likely to be pollution havens. Further being in a state of rather lower scientific development and with a tardy rate of industrialization, the developing economies may be slow in the absorption of low energy-saving technology. So, $\frac{E}{FDI}$ is likely to be on an increasing scale in such countries. It is normally held that FDI has a great role in shaping a country's industrial production sector. To encourage increased production and employment, developing countries often put stress on FDI inflows and in the process attract polluting industries, that provoke environmental pollution through fossil fuel-intensive industrial production. Thus $\frac{FDI}{IP}$ ratio indicates the contribution of FDI in total industrial production that is likely to have an adverse impact on the environment in developing economies. Further share of industrial production (composed of mining, manufacturing, electricity, and construction sectors) in total GDP is likely to release a large volume of GHGs into the atmosphere causing global warming and climate change. ε_{FFE} captures the aspect of elasticity of fossil fuel intensity of total energy use with respect to GDP. This value is expected to be positive in the case of developing countries where due to a lack of adequate funds for devising sufficient innovative technology, and a slower rate of diffusion of green technology, the use of renewable energy is yet to make deep inroads in the productive system. Further flagrant isolation of environmental norms and regulations, lax implementation of emission tax, tradable pollution permit, etc. have been instrumental in abetting the value of fossil fuel intensity of energy with respect to output growth. As developing countries start experiencing a higher level of growth, this elasticity is also likely to reveal a declining value with the substitution of fossil fuels for renewable components of energy. Again the expression ε_{EFDI} represents the elasticity of energy intensity of FDI with respect to GDP growth. It is expected that with output growth, the inflow of FDI will raise the level of energy use in the case of developing countries. To raise output levels developing countries often attract FDI by relaxing their environmental standards with the proliferation of energy-consuming polluting industries. Thus the spillover impact of FDI resists the decline in the level of energy intensity and this elasticity value is likely to be positive. The term ε_{FDIIP} indicates the elasticity of FDI intensity of industrial production with respect to growth in GDP. In the case of developing countries, high-technology export-oriented polluting industries gain significantly through FDI inflows indicating the possibility of pollution-haven effect. Thus with GDP growth and industrial output proliferation, the value of the above elasticity is likely to assume higher value and hence positive. ε_{IPYD} represents the elasticity of the proportion of industrial production in GDP with respect to GDP itself. With a rise in industrial production, there is likely to be a sectoral shift in production from the agricultural to the industrial sphere and hence this elasticity value is likely to be positive, betokening an increased FDI inflow, energy intensity, and fossil fuel usage that triggers environmental pollution through this chain.

RESULTS AND DISCUSSION

Let us consider the case of CO_2 emission. It is observed that under both the fixed effect and random effect, the coefficient of GDPPC is positive and highly significant, implying that with the rise in GDPPC, there is also an increase in CO_2 emission. As we know, the more rapid the pace of economic development, the greater the carbon dioxide emission.

Table 3. Result corresponding to the model of EKC

	CO_2 emission		N_2O emission		CH_4 emission	
	Random Effect	Fixed Effect	Fixed Effect	Random Effect	Fixed Effect	Random Effect
GDPPC	7.61E-13 (0.0000)*	8.35E-13 (0.0000)*	2.19E-08 (0.0000)*	2.29E-08 (0.0000)*	1.18E-11 (0.1001)***	1.39E-11 (0.0138)*
$GDPPC^2$	-4.99E-26 (0.0009)*	-5.50E-26 (0.0003)*	-7.01E-22 (0.0000)*	-7.73E-22 (0.0000)*	-1.36E-24 (0.0299)**	-1.30E-24 (0.0137)*
FFEC	0.062416 (0.0000)*	0.06327 (0.0000)*	90.7192 (0.0024)*	70.2791 (0.014)*	1.351875 (0.0000)*	0.866824 (0.0000)*
FDI	-0.001 (0.7681)	-0.00097 (0.7764)	1.94686 (0.9192)	1.53105 (0.9363)	0.2793 (0.0443)**	0.362432 (0.0086)*
PD	-0.00924 (0.0000)*	-0.01016 (0.0000)*	-14.2548 (0.0356)**	-12.1562 (0.048)**	0.261658 (0.0000)*	0.085555 (0.0009)*
R^2	0.20128	0.981819	0.99566	0.77441	0.735324	0.092843
F-stat	37.80051 (0.0000)*	965.2993 (0.0000)*	4096.55 (0.0000)*	514.919 (0.0000)*	49.66042 (0.0000)*	15.35179 (0.0000)*
Hausman	5.261448 (0.3848)		69.9822 (0.0000)		55.67902 (0.0000)	
Model	Random Effect		Fixed Effect		Fixed Effect	
EKC	Inverted U-shaped		Inverted U-shaped		Inverted U-shaped	
Author's calculation is based on the World Bank data source.						
Note: *, **, and *** indicate significance levels at 1%, 5% and 10% respectively.						

Table 4. Results corresponding to the impact of EDI, FDI and PD on HI

	Health Index(HI)	
	Random Effect	Fixed Effect
Intercept	0.54195 (0.0000)*	0.536329 (0.0000)*
EDI	-0.05763 (0.1364)***	-0.08786 (0.0285)**
FDI	0.005131 (0.0000)*	0.005018 (0.0000)*
PD	0.00086 (0.0000)*	0.000998 (0.0000)*
R^2	0.285195	0.972753
F-stat	66.49727 (0.0000)*	654.9739 (0.0000)*
Hausman	26.0148 (0.0000)*	
Model	Fixed Effect	
Author's calculation is based on the World Bank data source.		
Note: *,**, and *** indicate significance levels at 1%, 5% and 15% respectively.		

The coefficient of $GDPPC^2$ is negative and highly significant under both models as well, implying the existence of the EKC relationship. The coefficients of Fossil fuel energy consumption under both models are positive as well as highly significant, implying that fossil fuel energy consumption has a positive impact on CO_2 emission. Burning fossil fuels releases a large quantity of CO_2 into the atmosphere thus polluting it. FDI has a negative but insignificant impact on CO_2 emission under both the Fixed Effect and Random Effect models. The population density has a negative as well as a highly significant impact on CO_2 emission for both models as we have seen that, the higher population density in urban areas leads to more efficient use of land and reduces dependence on private vehicles which lowers the CO_2 emission into the atmosphere. From the Hausman test, it is observed that the value of the Chi-square is insignificant so we choose the random effect model. The value of R^2 appears to be 0.20128, with a significant F- statistic.

Secondly, we consider the case of N_2O emission. It is observed that under both the fixed effect and random effect, the coefficient of GDPPC is positive and highly significant, implying that with the rise in GDPPC, there is also an increase in N_2O emission. As we know, the more rapid the pace of economic development, the greater the nitrous oxide emission. The coefficient of $GDPPC^2$ is negative and highly significant under both models as well, implying the existence of the EKC relationship. The coefficients of Fossil fuel energy consumption under both models are positive as well as highly significant, implying that fossil fuel energy consumption has a positive impact on N_2O emission. Burning fossil fuels releases a large quantity of N_2O into the atmosphere thus polluting it. FDI has a positive but insignificant impact on N_2O emission under both the Fixed Effect and Random Effect models. The population density has a negative and highly significant impact on N_2O emission for both models. We have seen that the higher population density in urban areas leads to more efficient land use and reduces dependence on private vehicles, lowering the N_2O emission into the atmosphere. From the Hausman test, it is observed that the value of the Chi-square is highly significant so we choose the fixed effect model. The value of R^2 appears to be 0.99566, with significant F- statistics. Thirdly, we consider the case of CH_4 emission. It is observed that under both the fixed effect and random effect, the coefficient of GDPPC is positive and highly significant, implying that with the rise in GDPPC, there is also an increase in CH_4 emission. As we know, the more rapid the pace of economic development, the greater the methane emission. The coefficient of $GDPPC^2$ is negative and highly significant under both models as well, implying the existence of the EKC relationship. The coefficients of Fossil fuel energy consumption under both models are positive as well as highly significant, implying that fossil fuel energy consumption has a positive impact on CH_4 emission. The use of fossil fuels like natural gas and oil releases a large quantity of CH_4 into the atmosphere thus polluting it. FDI has a positive but significant impact on CH_4 emission under both the Fixed Effect and Random Effect models. Thus FDI has a positive impact on the emission of $CH_{4.}$ As FDI inflows increase, economic activity also increases which leads to the increase in methane emission. The population density has a positive as well as a highly significant impact on CH_4 emission for both models as we have seen that, higher population density implies greater combustion of fossil fuels which increases the emission of greenhouse gases like methane. The Hausman test shows that the value of the Chi-square is highly significant, so we choose the fixed effect model. The value of R^2 appears to be 0.735324, with a significant F- statistic.

The empirical results highlight the fact that the Health Quality Index is negatively related to the Environmental Degradation Index but positively related to both Foreign Direct Investment and Population Density. Table 4 above shows the Random Effect and Fixed Effect Model coefficients. To test the appropriateness between the two models we performed the Hausman Test. After performing the Hausman Test, the p-value is highly significant. As a result, we can conclude that the Fixed Effect Model is more appropriate than the Random Effect Model. It is observed that the coefficient for EDI is negative and highly significant. The economic explanation for this is that due to industrial emissions, vehicle emissions as well as deforestation the quality of the air degrades leading to several respiratory and cardiovascular diseases. A higher level of environmental degradation increases the level of toxic air pollutants in the atmosphere like sulphur dioxide(SO_2), nitrogen dioxide(N_2O), and carbon monoxide(CO) leading to the risk of infant mortality. Exposure to polluted air of would-be mothers and also other people over a longer period can lead to lung cancer as well which reduces the life expectancy at birth. Several waterborne diseases such as cholera, typhoid, etc. are caused by using water that gets contaminated by industrial wastes, agricultural runoff, improper waste disposal, etc. These waterborne diseases as well as some vectorborne diseases are very dangerous for pregnant women due to their weak immunity system leading to the increased risk of maternal mortality and reduced life expectancy as well. As a result of the increase in the emission of greenhouse gases, there arises extreme weather condition, natural disasters, etc. which has an adverse impact on health leading to certain stress-related health conditions. However, the destruction of the ecosystem and the loss of biodiversity also affects public health adversely leading to the spread of several diseases.

It is observed in the above table that Foreign Direct Investment(FDI) has a positive impact on the health index. The reason is that FDI increases the growth of the economy leading to an increase in national income. A higher level of income allows the government to spend on healthcare infrastructure and facilities improving public health. FDI can directly fund the development of healthcare clinics, medical equipment, etc which leads to better access to medical facilities. Multinational companies also invest in some health sectors leading to the improvement in the availability and quality of medical products as well as services. Population density also affects the health index positively. It may be so that better healthcare services are easily accessible in densely populated areas. Various healthcare facilities like clinics, hospitals, etc. are generally found where they can provide services to most people, often in urban, densely populated areas. As people can make easy and quick access to the medical facilities this leads to better health outcomes. It is also much more cost-effective to implement public health programs in densely populated urban areas which can control several diseases better, thus leading to better health outcomes.

Concluding Observations and Policy Prescriptions: The Environmental Kuzents Curve (EKC) shows the relationship between environmental degradation and economic growth. The EKC is found to be of the usual inverted U-shape for the considered developing countries. In such cases, as economic growth increases, environmental degradation also increases, and after reaching a threshold level of income the environmental degradation is found to decrease with a further rise in economic growth. However, not all developing nations may necessarily reach the threshold level where environmental quality improves. The state of GDP reached in particular countries may have different levels of impact on the emission pattern of individual gases. The emission of greenhouse gases (CO_2, CH_4, and N_2O) also affects health to a great extent by increasing the level of pollution in the atmosphere, as a result of which the productivity of labour decreases leading to a decrease in industrial production.

Based on the outcome of this article, it appears that the FFEC exerts a positive impact on the emission of greenhouse gases while the FDI and PD exert a negative impact on greenhouse gas emissions. To reverse this positive impact of FFEC on the emission of greenhouse gases efforts should be taken by reducing deforestation and increasing afforestation that will serve as a carbon pool, imposing a tax on carbon emission on the polluting industries to reduce the level of carbon use. The government of each country should also make efforts to encourage the use of clean renewable sources of energy. More focus is required to be given by the government on the innovative use of solar energy, and wind energy as well as on environment-friendly fossil fuels(CNG) to run cars which can reduce the level of pollution in the atmosphere. Vehicles that run on LPG emit less harmful substances into the atmosphere as compared to traditional road fuels (petrol, diesel, etc.) which harms health as well.

To raise the level of FDI, the government should develop transportation facilities and communication networks to facilitate business operations and invest in education and training to create a skilled workforce. The government should identify and promote sectors with high potential for sustainable development such as renewable energy, sustainable agriculture, etc. The government should also facilitate the transfer of technology from foreign investors to local small and medium-sized enterprises to improve their capacity for sustainable development. Further policies encouraging population density involve the development of well-planned urban areas with adequate housing and healthcare facilities, improved access to social services, and implementation of policies that ensure sustainable development. As a whole, proper measures are to be taken to lessen maternity pressure on the environment and improve air quality, thus ensuring the ecosystem's preservation.

Appendix

Table A1. Descriptive Statistics of explanatory variables in the EKC equation

	GDP	FFEC	FDI	PD
Mean	6.06E+11	55.36057	3.78365	124.1756
Median	1.77E+11	60.53882	2.30208	58.12931
Maximum	9.15E+12	99.95791	103.3374	1286.172
Minimum	2.99E+09	6.001886	-3.08352	7.931927
Range	9.15E+12	93.95602	106.4209	1278.24

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