Factors influencing Carbon Dioxide Emission and Air Pollution

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The purpose of this study is to determine the effect of various factors on carbon dioxide emission and air pollution. Data from four (4) different countries (Australia, Turkey, Egypt and Mozambique) classified by income levels (High, Middle, Lower Middle and Low) are chosen for the study. Multiple linear regression would be used to establish a relationship between the variables. This study would also verify the presence of Environment Kuznets Curve (EKC) hypothesis in the panel of countries. The study would also investigate how economic growth, energy consumption, environment policies and investment play a role in global emissions and air pollution. The research would also help in recommending measures to mitigate environment degradation without hampering economic growth. The recommendation from this study will put the humanitarian consequences of climate change much higher on the international agenda and investing more in preparedness and risk reduction.

1. Introduction:

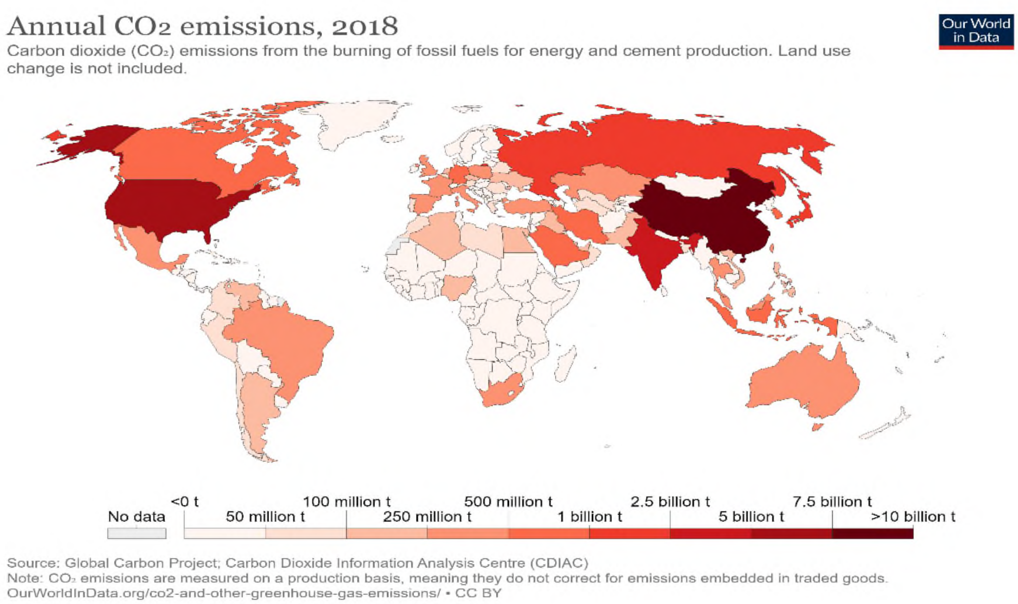


Figure 1: Global Annual CO2 Emissions

According to a report, compiled by Oxfam and the Stockholm Environment Institute, the rampant overconsumption and the rich world's addiction to high-carbon transport are exhausting the world's "carbon budget". The wealthiest 1% of the world's population were responsible for the emission of more than twice as much carbon dioxide as the poorer half of the world from 1990 to 2015. Carbon dioxide emissions rose by 60% over the 25-year period, but the increase in emissions from the richest 1% was three times greater than the increase in emissions from the poorest half [12].
The richest 10% of the global population, comprising about 630 million people, were responsible for about 52% of global emissions over the 25-year period. Globally, the richest 10% are those with incomes above about $35,000 (£27,000) a year, and the richest 1% are people earning more than about $100,000. Carbon

dioxide emissions accumulate in the atmosphere, causing heating, and temperature rises of more than 1.5 ^{0}C above pre-industrial levels would cause widespread harm to natural systems. That accumulation

gives the world a finite carbon budget of how much carbon dioxide it is safe to produce, which scientists warn will be exhausted within a decade at current rates [14].

In this project, we would explore how a country's economic and infrastructure development causes changes (good/bad) in the environment. We would explore various models by using different dependent and independent variables to explain the relation between environment and economic development, government policies and other parameters. The objective would be to establish a relation between a country's development and its effect on the environment through Regression Analysis and verify Environment Kuznets Curve (EKS).

It is very crucial that we start considering this problem now. If left unchecked, in the next decade the carbon emissions of the world's richest 10% would be enough to raise levels above the point likely to increase temperatures by 1.5 ^{0}C, even if the whole of the rest of the world cut their emissions to zero immediately, according to Monday's report.

The seven oil-rich countries chosen in the study by M. K. Ardakania and S. M. Seyedaliakbarb [1] comprises of five countries in the high-income category and rest two in the middle-income category. Carbon dioxide emissions from these countries is continuously reducing with economic growth since these countries have already passed their peak emission and would not reflect a correct picture of the global emissions. In developing countries, the carbon dioxide emission is increasing with economic growth, since the growth is driven by large scale energy consumption and lesser environment reforms. The results and observations from this study would have been more accurate if the panel of countries comprised of different income categories. The regression analysis and its coefficient would not be a correct representation of the global CO_2 emission and may lead to wrong conclusions.

The gap in the literature due to possible inaccurate model can be addressed by selecting countries with different income levels, since the data from these countries would be an accurate representation of global situation. Data from different income groups would account for the variations in the carbon dioxide emissions and economic growth. Also, the relationship between CO_2 emissions and economic growth would be accurate because the data would correctly capture the actual emissions with economic growth. The gap can be further reduced by introducing interaction terms which can capture the simultaneous effect of independent variables on the dependent variable.

The objective of this study is to understand the effects of Energy consumption, Economic growth, Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption and Foreign Direct Investment on environment in terms of CO2 Emissions and Air Quality. This would help to inform current authorities about emission projections and protect our surroundings well before it's too late.

Our study will contribute to the studies on risks that unchecked carbon emission and air pollutants pose on the environment. The research would also give recommendations to mitigate environmental degradation without affecting economic growth.

We are proposing to analyze the following four countries according to different income levels:

Country 1: Australia (High Income)

Country 2: Turkey (Middle Income)

Country 3: Egypt (Lower Middle Income)

Country 4: Mozambique (Low Income)

2. Literature Review:

Several research studies have shown that Carbon Dioxide emission and Air Quality in the developed and developing countries are affected by several factors such as energy consumption, economic growth, foreign investment, environment policies, etc. In this section, we would review some studies which examined the relationship between these factors on the CO_2 emission and air quality in different countries.

One such study by M. K. Ardakania and S. M. Seyedaliakbarb (2019) [1] investigates the impact of energy consumption and economic growth on CO2 emission in seven oil-abundant MENA countries, over the period of 1995–2014. In this multivariate regression, the predictor variables are EPC, GDP, and GDP^2, and the response variable is CO2. The study verifies EKC postulates that when economic growth reaches its turning point, increase in GDP leads to environmental improvements. The study finds that in some countries when the GDP is less than its turning point, the economic growth causes more CO2 emission; however, after the GDP goes beyond its turning point the environmental quality improves. In few other countries, after GDP passes its turning point, CO2 emission starts to increase with economic growth.

Accordingly, implementation of appropriate economic and social policies is recommended for these countries to decrease CO2 emission while improving economic growth.

In a study by H. Borhan, E.M. Ahmed and M.Hitam (2012) [7], environmental degradation in the form of air pollution was analyzed for a panel of ASEAN 8 countries. An empirical relationship between air pollution, GDP, FDI, and other predictor variables is established and analysis is done on these relationships. The results indicate that CO_2 shows a negative significant relationship with income. This is explained by the theory that as pollution level increases income decreases in which pollution may directly decrease output by decreasing productivity of man-made capital and labor. The presence of health problems causes losses of labor-day; because of polluted air or water there are deteriorations in the quality of industrial equipment. The coefficient of air pollution indicator shows a significant effect on population density and CO_2 having a negative relationship with population density. This indicates that as pollution increases, population density decreases, which is linked to death of the population in ASEAN 8.

A.Hargrove, M.Qandeel and J.M. Sommer (2019) [8], conducts a regression analysis for testing how 24 multilateral environmental treaties with an energy focus, impact CO2 emissions per capita, CO2 emissions as a percentage of gross domestic product, and total CO2 emissions for 162 nations from 1996 to 2011. The findings are that the cumulative ratification of multilateral agreements seems to be reducing CO2 emissions in different countries. Environmental multilateral energy treaty ratification stocks often reduce CO2 outputs more in nations with higher levels rather than lower levels of state-led governance, especially control of corruption and government effectiveness. Also, higher levels of renewable energy consumption are associated with lower levels of all three measures of CO2 emissions. Higher levels of GDP per capita correspond with more CO2 emissions, which is likely due to higher levels of consumption in more wealthy nations. The findings provide evidence that the legitimacy of global contracts impacts actual decreases in carbon dioxide emissions, resulting in climate justice outcomes.

A study by S. Ozakcu and O. Ozdemir (2017) [9] investigates the relationship between income and Carbon Dioxide (CO2) emissions in the context of the Environmental Kuznets Curve (EKC), which posits the existence of an inverted U-shape relationship between environmental degradation and economic development. For this purpose, two empirical models are examined. For both models, the relationship between per capita income and per capita CO2 emissions and the relationship among per capita income, per capita energy use, and per capita CO2 emissions are analyzed respectively between 1980 and 2010. In the first model, data are analyzed for 26 OECD countries with high income levels, while for the second model, data are examined for 52 emerging countries. The analysis did not confirm that CO2 emissions increase along with the increase in income until the turning point and decline due to higher levels of income. The results from the analysis revealed that the policies for reducing the GHGs emissions seem insufficient as permanent patterns for reducing CO2 emission is not observed for the chosen countries and cases. The results can be used to infer that binding agreement on global, national, and local level for reducing CO2 emission is urgently needed to mitigate or adapt to climate change.
Apart from the hypothesis of Environment Kuznets Curve (EKC), this research by K. Zaman and M. Moemen (2017) [10] explores other hypotheses such as Pollution Haven Hypothesis (PHH), population based emissions (IPAT), energy led emissions, sectoral growth emissions and Emissions emancipated Human Development Index (eHDI) in the context of low and middle income countries, high income countries. The results from the regression analysis do not show any visible sign of eHDI and PHH in the panel of selected countries. The sectoral growth associated emissions including industry value added tend to increase CO2 emissions in low and middle income countries, and high income countries, while agricultural value added decreases the CO2 emissions in the panel of total 90 selected countries. In evaluating IPAT hypothesis, population growth increases CO2 emissions in the panel of high-income countries. The impact of energy demand on CO2 emissions is positive and significant in the panel of selected countries. The results of the study emphasized the strong policy vista for environmental sustainability across the globe. This study is designed to evaluate environmental resource policy to attract the policy makers to device long-term sustainability policies for better health and wealth.

3. <u>Methods:</u>

This study investigates the inverse effect of energy consumption, CO2 emissions and economic growth on each other in developed, emerging and low-income countries. The current study would be helpful to make suitable policies for the use of energy and utilization of clean energy in developed and developing economies which will increase their economies along with better utilization of the resources. In the first model, we are investigating the impact of energy consumption and economic growth on CO2 emission using multivariate regression. In the second and third model, we are testing the relationship of Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI on Air Quality. With the help of Regression Analysis and Environment Kuznets Curve (EKS), we will be trying to explain the relationship between the above mentioned dependent and independent variables.

Mathematical Representation of Models

Model 1: Impact of energy consumption and economic growth on CO_2 emission using multivariate regression [1]. This is taken up as a replication study.

$$\ln(CO_2\ Emission) = a + b1 * \ln(EPC) + b2 * \ln(GDP) + b3 * (\ln(GDP))^2 + \epsilon$$

CO_2 Emission is a dependent variable.

EPC (Electric Power Consumption), GDP are independent variables. ϵ is the error term.

Model 2: Relationship of Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI on CO_2 emission [2,3,4,5,6].

$$CO_2\ Emission = a + b1 * Env\ Pol + b2 * GDP + b3 * Elec\ Cons + b4 * RE\ Cons + b5 * FDI + \epsilon$$

CO_2 Emission is a dependent variable.

Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI are independent variables. ϵ is the error term.

Model 3: Relationship of Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI on Air Quality [2,3,4,5,6].

$$Air\ Quality = a + b1 * Env\ Pol + b2 * GDP + b3 * Elec\ Cons + b4 * RE\ Cons + b5 * FDI + \epsilon$$

Air Quality is a dependent variable.

Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI are independent variables. ϵ is the error term.

The normality of the data is checked using hypothesis testing where the data distribution for CO_2 Emission rate and air quality for different countries are assumed to be normal (H_o) and the test is conducted. We have defined the alternative hypothesis as the sample data is not normally distributed. The interesting findings from these tests is that all the countries irrespective of the income level have the data figures not normally distributed for the CO_2 Emissions and three out of the four countries depict normal behavior for air quality data. The distribution for air quality data of Turkey is not normal and also its Environment Kuznets Curve exhibits this behavior.

Hypothesis 1: H0: Carbon Dioxide emission increase with increasing economic growth.

Ha: Carbon Dioxide emissions decrease with increasing economic growth.

This hypothesis would confirm that a country's economic growth is either sustainable or is at the expense of environment. A sustainable growth should be perpetuated, and more reforms should be made to continue the momentum. An unsustainable growth should be mitigated by introducing stringent environmental policies and environment watchdogs introducing measures to monitor the emissions.

Hypothesis 2: H0: Carbon dioxide emissions decrease with increasing Environment Sustainability Policy rating.

Ha: Carbon dioxide emissions do not decrease with increasing Environment Sustainability Policy rating.

Hypothesis 2 would confirm the assumption that a country's carbon dioxide emission reduces on the grounds of improving environment policies that regulate activities and emission norms. A good environment sustainability rating is achieved through assessment of the extent to which environmental policies foster the protection and sustainable use of natural resources and the management of pollution. Implementation of policies requires government effectiveness, regulatory quality, no corruption, etc. Lack of these measures would result in inefficacy of environment policies and would require international intervention.

Hypothesis 3: H0: Air Pollution decreases with increasing Environment Sustainability Policy rating.

Ha: Air Pollution does not decrease with increasing Environment Sustainability Policy rating.

Hypothesis 3 would confirm the assumption that a country's air pollution reduces on the grounds of improving environment policies that regulate activities and emission norms. A good environment sustainability rating is achieved through assessment of the extent to which environmental policies foster the protection and sustainable use of natural resources and the management of pollution. Implementation of policies requires government effectiveness, regulatory quality, no corruption, etc. Lack of these measures would result in inefficacy of environment policies and would require international intervention.

Hypothesis 1 assumes direct positive relationship between carbon dioxide emissions and economic growth. This hypothesis challenges the existing literatures by Mostafa & Seyed (2019) [1] and S. Ozakcu & O. Ozdemir (2017) [9] which verifies the assumption of Environment Kuznets Curve (EKC) hypothesis which is "The earlier stage of economic development shows a positive relationship between low GDP per capita and environmental quality, but later, there is a negative relationship between higher level of growth or higher GDP per capita and environmental quality."

Most of the studies done on the relationship between carbon dioxide emission and economic growth has argued about the existence of a U-shaped relation. The U-shaped relation can be inverted or not inverted. The hypothesis 1 assumes a linear relationship between economic growth and carbon dioxide emission which is in stark contrast to different studies that claim a non-linear relation. The studies argue that for some countries at early stages economic growth causes environmental degradation up to a certain point and afterwards the environment degradation reduces with increasing economic growth. A linear relation would either continuously degrade environment or will not degrade environment with economic growth.

Intuitively, a country's continued process of growth aggravates the greenhouse gas emissions phenomenon. In this regard, we cannot provide any evidence that developed countries may actually grow-out of environmental pollution. There seems to be an ethical dilemma, between high economic growth rates and unsustainable environment and low or zero economic growth and environmental sustainability [11].

In the light of these findings, the efficacy of recent government policies in various countries to promote renewable energy consumption as a means for sustainable growth is questioned. At the same time, it puts forward the argument that perhaps decisions should be made not on the basis of how developed societies may sustain current levels of growth by employing renewable energy consumption strategies (as this might in fact be an infeasible approach in the long run), but rather, to concentrate on more communally just ways and ideas of social conduct such as the ones endorsed by the process of degrowth or a-growth [11].

4. Data

Discussion on variables in each model:

- **Model 1:** The CO_2 emission from different countries makes up the largest share of the “greenhouse gases”. This is leading to an increase in the earth's surface temperature and to related effects on climate, sea level rise and world agriculture. The aim is to investigate how CO_2 emission is affected by energy consumption (Electric Power Consumption-EPC) and GDP (Gross Domestic Product), since energy consumption and GDP are some of the measures of economic growth of a country. Basically, as the economy grows, more carbon dioxide is released perhaps due to more industrial activities without employing environmentally friendly techniques that should enhance environmental quality [1].
- **Model 2:** The aim is to explore the effect of sustainable environment policies (EnvPol), FDI (Foreign Direct Investment), Renewable Energy Consumption (RECons), Electric Power Consumption (EPC) and GDP on a country’s CO_2 emission. The variables FDI, GDP and Electric Power Consumption are directly linked to a country’s economic growth, whereas the variables environment policies and renewable energy consumption measures a country’s action on building a sustainable environment. The relationship between economic growth and the pressure on nature from the environmental sustainability perspective depends on the environment friendly policies like usage of solar energy to generate electric power for businesses etc. Unbalanced availability between finite energy resources and industrial development may lead to decrease in the environment quality, despite the rising income [2,3,4,5,6].
- **Model 3:** The deterioration of air quality from industrial emissions and other sources that are well beyond the control of individuals has triggered public concerns and has inspired heated debates on the trade-off between air quality and economic growth. The aim is to explore the effect of sustainable environment policies (EnvPol), FDI (Foreign Direct Investment), Renewable Energy Consumption (RECons), Electric Power Consumption (EPC) and GDP on a country’s air quality (PM 2.5). The variables FDI, GDP and Electric Power Consumption are directly linked to a country’s economic growth, whereas the variables environment policies and renewable energy consumption measures a country’s action on building a sustainable environment. For some countries, the policies related to FDI, energy generation aimed to encourage economic growth have detrimental consequences on air quality at different stages of country’s development [2,3,4,5,6].

Refer to Appendix-A for information on variables containing variable definition, type, construction and source.

Descriptive Statistics (Countrywise):

The descriptive statistics for the independent and dependent variables mentioning the mean, median, mode, standard deviation, variance, range, maximum and minimum and the count. The data has been summarized in Table-1 to Table-4.

1. Australia

Variables / *Descriptive Statistic*	*CO2 emissions (kt)*	*Electric power consumption (kWh per capita)*	*GDP (constant 2010 US$)*	*Foreign direct investment, net inflows (% of GDP)*	*Renewable energy consumption (% of total final energy consumption)*	*CPIA policy and institutions for environmental sustainability rating (1=low to 6=high)*	*PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)*
Mean	339199.46	9939.10	989B	2.88	8.07	1.60	10.04
Median	342699.49	10220.89	980B	3.26	8.25	1.19	10.42
Standard Deviation	43804.68	845.15	269B	1.86	0.83	1.12	0.85
Sample Variance	1918850275	714272.94	7,211,842,328,3T**	3.47	0.69	1.26	0.72
Range	133321.12	2450.73	837B	10.62	2.60	3.61	2.50
Minimum	261471.77	8522.16	610B	-3.62	6.68	0.46	8.55
Maximum	394792.89	10972.89	1448B	7.01	9.28	4.07	11.05
Count	29	25	30	30	26	26	12

Table-1: Descriptive Statistics of Australia

Note 1- ‘M’ stands for ‘Million’

Note 2- ‘B’ stands for ‘Billion’

Note 3- ‘T’ stands for ‘Trillion’

2. Turkey

Variables / *Descriptive Statistics*	*CO2 emissions (kt)*	*Electric power consumption (kWh per capita)*	*GDP (constant 2010 US$)*	*Foreign direct investment, net inflows (% of GDP)*	*Renewable energy consumption (% of total final energy consumption)*	*CPIA policy and institutions for environmental sustainability rating (1=low to 6=high)*	*PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)*
Mean	248903.25	1828.21	700B	1.22	17.68	1.03	42.80
Median	225421.49	1667.36	631B	1.17	17.02	0.69	42.60
Standard Deviation	75806.59	618.25	283B	0.89	4.48	0.64	1.44
Sample Variance	5746638806.22	382235.49	80279488081T	0.80	20.07	0.41	2.06
Range	232636.82	1917.43	886B	3.35	12.90	2.00	4.86
Minimum	145994.27	929.70	365B	0.31	11.61	0.21	40.55
Maximum	378631.09	2847.13	1251B	3.65	24.51	2.21	45.40
Count	29	25	30	30	26	26	12

Table-2: Descriptive Statistics of Turkey

Note 1- ‘M’ stands for ‘Million’

Note 2- ‘B’ stands for ‘Billion’

Note 3- ‘T’ stands for ‘Trillion’

3. Egypt

Variables / *Descriptive Statistics*	*CO2 emissions (kt)*	*Electric power consumption (kWh per capita)*	*GDP (constant 2010 US$)*	*Foreign direct investment, net inflows (% of GDP)*	*Renewable energy consumption (% of total final energy consumption)*	*CPIA policy and institutions for environmental sustainability rating (1=low to 6=high)*	*PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)*
Mean	155169.44	1139.78	173B	2.37	7.33	2.9	77.69
Median	149437.58	1078.95	159B	1.48	7.47	2.75	75.84
Standard Deviation	54559.10	367.66	65B	2.32	1.38	0.32	6.38
Sample Variance	2976694937.87	135172.47	4287940566T	5.40	1.90	0.11	40.77
Range	163020.15	1008.00	215B	9.55	4.27	1	17.43
Minimum	75540.20	677.82	87B	-0.20	5.55	2.5	70.79
Maximum	238560.35	1685.82	302B	9.34	9.83	3.5	88.21
Count	28	25	30	30	26	15	12

Table-3: Descriptive Statistics of Egypt

Note 1- ‘M’ stands for ‘Million’

Note 2- ‘B’ stands for ‘Billion’

Note 3- ‘T’ stands for ‘Trillion’

4. Mozambique

Variables / ***Descriptive Statistics***	***CO2 emissions (kt)***	***Electric power consumption (kWh per capita)***	***GDP (constant 2010 US$)***	***Foreign direct investment, net inflows (% of GDP)***	***Renewable energy consumption (% of total final energy consumption)***	***CPIA policy and institutions for environmental sustainability rating (1=low to 6=high)***	***PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)***
Mean	2455.260222	262.3435896	8679.5M	10.53	92.33565892	3.3	22.54115069
Median	1822.499	277.3587457	7483.47M	5.38	92.88030691	3.5	22.64969531
Mode	1023.093	#N/A	#N/A	#N/A	#N/A	3.5	#N/A
Standard Deviation	2046.564932	192.2075293	5029.77M	11.26	1.800615152	0.253546276	0.678701025
Sample Variance	4188428.021	36943.73432	2.52986E+19	126.86	3.242214926	0.064285714	0.460635082
Range	7429.342	436.7260788	15067.72M	38.85	7.898500052	0.5	2.26277326
Minimum	1004.758	42.19509348	2765.31M	0.61	86.40050892	3	21.29869546
Maximum	8434.1	478.9211723	17833.03M	39.46	94.29900897	3.5	23.56146872
Count	27	25	30	29	26	15	12

Table-4: Descriptive Statistics of Mozambique

Note 1- ‘M’ stands for ‘Million’

Note 2- ‘B’ stands for ‘Billion’

Note 3- ‘T’ stands for ‘Trillion’

5. Results

5.1. Normality Test of Dependent Variables

We ran Kolmogorov-Smirnov & Shapiro-Wilk test in R for checking the normality of carbon dioxide emissions and air pollution for sample data from the countries.
The hypothesis for testing the data at 5% significance level was as follows:
Ho: The sample exhibits normal distribution
Ha: The sample does not exhibit normal distribution

Dependent Variable	Data Distribution Histogram	Kolmogorov-Smirnov Test (R Output)	Shapiro-Wilk Test (R Output)	Comments
Carbon Dioxide Emission	Not Normal (The data distribution does not fit normal distribution) (Figure-2)	One-sample Kolmogorov-Smirnov test data: CO2_Emis D = 1, p-value < 2.2e-16 alternative hypothesis: two-sided	Shapiro-Wilk normality test data: CO2_Emis W = 0.90817, p-value = 1.004e-06	The result from both K-S and S-W test are significant since p-value < 0.05. Hence, we reject the null hypothesis and conclude that the data is not normally distributed.
Air Pollution	Not Normal (The data distribution does not fit normal distribution) (Figure-3)	One-sample Kolmogorov-Smirnov test data: AQ D = 1, p-value < 2.2e-16 alternative hypothesis: two-sided	Shapiro-Wilk normality test data: AQ W = 0.86902, p-value = 7.243e-05	The result from both K-S and S-W test are significant since p-value < 0.05. Hence, we reject the null hypothesis and conclude that the data is not normally distributed.

Table-5: Summary of Normality Tests

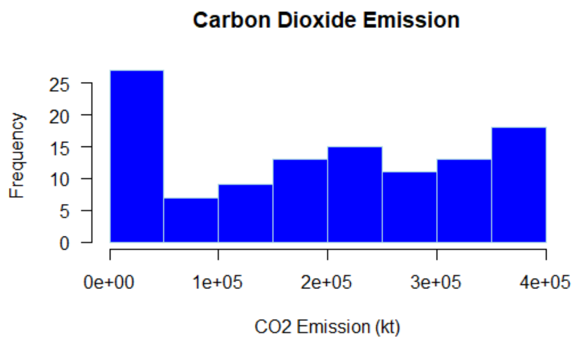


Figure-2: CO2 Emission Histogram

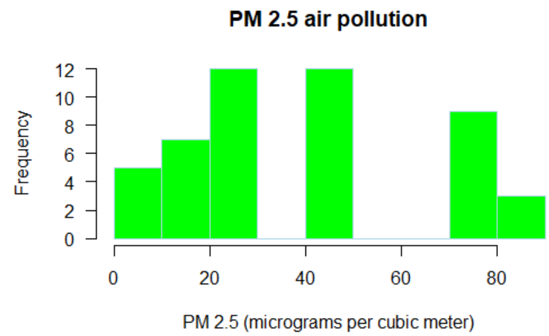


Figure-3: Air Pollution Histogram

5.2. Independency in Dependent Variables

The average values of dependent variables were compared (for different pairs of countries) using two sample two tail paired t-test at 5% significance level.
The following hypothesis was used for comparing the population mean for both dependent variables (CO2 Emission and Air Pollution):
Ho: Population mean of CO2 emission/Air Pollution for the compared countries are equal.

Ha: Population mean of CO2 emission/Air Pollution for the compared countries are different.

The two sample two tail t-test comparison of means of **Carbon Dioxide Emissions** for different combination of countries is summarized in the six (6) tables (tables 6-11).

	Australia	***Turkey***
Mean	339199.5	248903.2
Variance	1.92E+09	5.75E+09
Observations	29	29
Pooled Variance	3.83E+09	
Hypothesized Mean Difference	0	
df	56	
t Stat	5.553907	
P(T<=t) one-tail	3.99E-07	
t Critical one-tail	1.672522	
P(T<=t) two-tail	7.98E-07	
t Critical two-tail	2.003241	

	Australia	***Egypt***
Mean	339199.5	155169.4
Variance	1.92E+09	2.98E+09
Observations	29	28
Pooled Variance	2.44E+09	
Hypothesized Mean Difference	0	
df	55	
t Stat	14.0669	
P(T<=t) one-tail	3.63E-20	
t Critical one-tail	1.673034	
P(T<=t) two-tail	7.26E-20	
t Critical two-tail	2.004045	

	Australia	*Mozambique*
Mean	339199.5	2455.260222
Variance	1.92E+09	4188428.021
Observations	29	27
Pooled Variance	9.97E+08	
Hypothesized Mean Difference	0	
df	54	
t Stat	39.87903	
P(T<=t) one-tail	4.81E-42	
t Critical one-tail	1.673565	
P(T<=t) two-tail	9.63E-42	
t Critical two-tail	2.004879	

	Turkey	*Egypt*
Mean	248903.2	155169.4
Variance	5.75E+09	2.98E+09
Observations	29	28
Pooled Variance	4.39E+09	
Hypothesized Mean Difference	0	
df	55	
t Stat	5.341467	
P(T<=t) one-tail	9.07E-07	
t Critical one-tail	1.673034	
P(T<=t) two-tail	1.81E-06	
t Critical two-tail	2.004045	

	Turkey	*Mozambique*
Mean	248903.2	2455.26022
Variance	5.75E+09	4188428.02
Observations	29	27
Pooled Variance	2.98E+09	
Hypothesized Mean Difference	0	
df	54	
t Stat	16.87626	
P(T<=t) one-tail	1.72E-23	
t Critical one-tail	1.673565	
P(T<=t) two-tail	3.43E-23	
t Critical two-tail	2.004879	

	Egypt	*Mozambique*
Mean	155169.4	2455.26022
Variance	2.98E+09	4188428.02
Observations	28	27
Pooled Variance	1.52E+09	
Hypothesized Mean Difference	0	
df	53	
t Stat	14.5296	
P(T<=t) one-tail	1.99E-20	
t Critical one-tail	1.674116	
P(T<=t) two-tail	3.99E-20	
t Critical two-tail	2.005746	

From the results of t-test, we find that the results are significant and we can reject the null hypothesis. Hence, the Carbon Dioxide Emission of each country do not come from the same population and the emission data is independent of each other.

The mean emission (in kt) ranking order is as follows:

1. Australia = 339199.45
2. Turkey = 248903.25
3. Egypt = 155169.44
4. Mozambique = 2455.26

Australia has the largest mean value and Mozambique has the smallest mean value of CO2 Emission.

Australia's Emission 95% Confidence Interval: 322537.046 < µ < 355861.87

Mozambique's 95% Confidence Interval: 1645.67 < μ < 3264.85

The confidence intervals give us the estimation of mean emission in the population. The population here represents the emissions of all countries on earth. Hence, we can confidently say that 95 out of 100 countries would have mean carbon dioxide emissions (in kt) between a minimum of 1645.67 to a maximum of 355861.87.

The two sample two tail t-test comparison of means of **Air Pollution** for different combination of countries is summarized in the six (6) tables (tables 12-17) below.

	Australia	***Turkey***
Mean	10.03732	42.80057
Variance	0.719286	2.060114
Observations	12	12
Pooled Variance	1.3897	
Hypothesized Mean Difference	0	
df	22	
t Stat	-68.0773	
P(T<=t) one-tail	2.21E-27	
t Critical one-tail	1.717144	
P(T<=t) two-tail	4.41E-27	
t Critical two-tail	2.073873	

	Australia	***Egypt***
Mean	10.03732	77.68954
Variance	0.719286	40.7668
Observations	12	12
Pooled Variance	20.74304	
Hypothesized Mean Difference	0	
df	22	
t Stat	-36.3849	
P(T<=t) one-tail	1.89E-21	
t Critical one-tail	1.717144	
P(T<=t) two-tail	3.77E-21	
t Critical two-tail	2.073873	

	Australia	***Mozambique***
Mean	10.03732	22.5411507
Variance	0.719286	0.46063508
Observations	12	12
Pooled Variance	0.589961	
Hypothesized Mean Difference	0	
df	22	
t Stat	-39.8756	
P(T<=t) one-tail	2.59E-22	
t Critical one-tail	1.717144	
P(T<=t) two-tail	5.18E-22	
t Critical two-tail	2.073873	

	Turkey	***Egypt***
Mean	42.80057	77.68954
Variance	2.060114	40.7668
Observations	12	12
Pooled Variance	21.41346	
Hypothesized Mean Difference	0	
df	22	
t Stat	-18.468	
P(T<=t) one-tail	3.5E-15	
t Critical one-tail	1.717144	
P(T<=t) two-tail	7E-15	
t Critical two-tail	2.073873	

	Turkey	*Mozambique*
Mean	42.80057	22.541151
Variance	2.060114	0.4606351
Observations	12	12
Pooled Variance	1.260375	
Hypothesized Mean Difference	0	
df	22	
t Stat	44.20311	
P(T<=t) one-tail	2.76E-23	
t Critical one-tail	1.717144	
P(T<=t) two-tail	5.51E-23	
t Critical two-tail	2.073873	

	Egypt	*Mozambique*
Mean	77.68954	22.54115069
Variance	40.7668	0.460635082
Observations	12	12
Pooled Variance	20.61372	
Hypothesized Mean Difference	0	
df	22	
t Stat	29.75297	
P(T<=t) one-tail	1.45E-19	
t Critical one-tail	1.717144	
P(T<=t) two-tail	2.9E-19	
t Critical two-tail	2.073873	

From the results of t-test, we find that the results are significant and we can reject the null hypothesis. Hence, the Air Pollution of each country do not come from the same population and the pollution data is independent of each other.

The mean air pollution (in micrograms per cubic meter) ranking order is as follows:

1. Australia = 10.037500
2. Turkey = 42.800000
3. Egypt = 77.690000
4. Mozambique = 22.541151

Egypt has the largest mean value and Australia has the smallest mean value of Air Pollution (PM2.5 air pollution).

Egypt's Pollution 95% Confidence Interval: $73.64 < \mu < 81.75$

Australia's Pollution 95% Confidence Interval: $9.50 < \mu < 10.58$

The confidence intervals give us the estimation of mean pollution in the population. The population here represents the emissions of all countries on earth. Hence, we can confidently say that 95 out of 100 countries would have mean air pollution (PM 2.5) between a minimum of 9.5 to a maximum of 81.75

5.3. Multiple Regression Analysis

Model 1: Impact of energy consumption and economic growth on CO2 emission using multivariate regression [1]. This is taken up as a replication study.

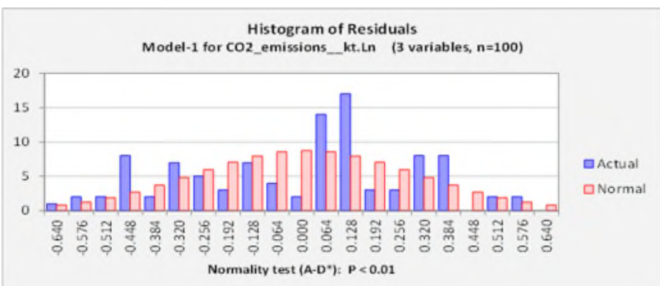
The multiple regression output from Excel's RegressIt is as follows:

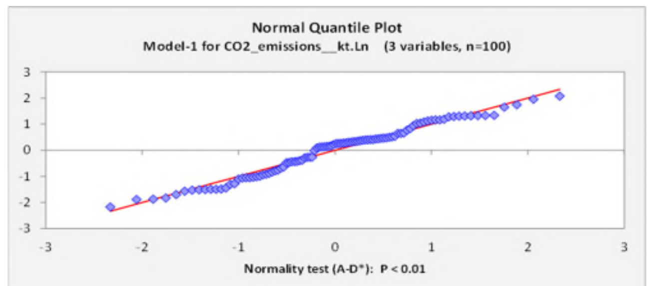
$$Ln(CO2\ Emission) = -90.65 - 0.11Ln(EPC) + 7.08Ln(GDP) - 0.12\big(Ln(GDP)\big)\text{^}2$$

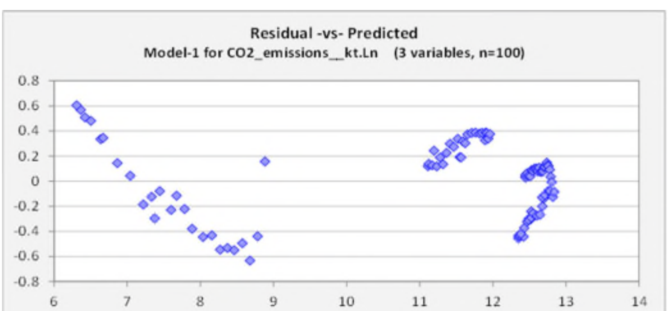
Regression Statistics	
R-Squared	0.982
Adj.R-Sqr.	0.981
Std.Err.Reg.	0.30
Std.Dep.Var.	2.15
# Fitted	100
# Missing	20
Critical t	1.98
Confidence	95.00%

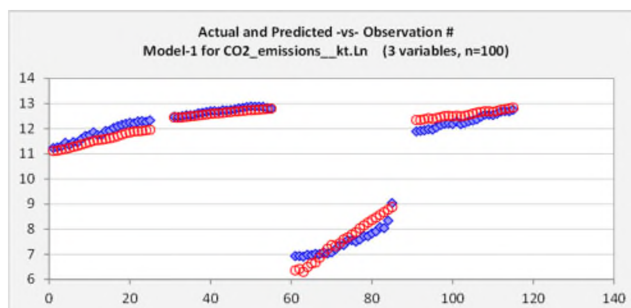
ANOVA			
Source	Regression	Residual	Total
Deg. Freedom (df)	3.00	96.00	99.00
Sum Squares (SS)	447.46	8.40	455.86
Mean Square (MS)	149.15	0.09	-
F-Statistic (F)	1704.76	-	-

Variable	Coefficient	Std.Err.	t-Statistic	P-value	Lower95%	Upper95%	VIF	Std. Coeff.
Constant	-90.65	6.48	-13.98	7E-25	-103.52	-77.78	0.00	0.00
Ln(EPC)	-0.11	0.05	-2.29	0.024	-0.20	-0.01	6.01	-0.08
Ln(GDP)	7.08	0.52	13.49	7E-24	6.03	8.12	1237.12	6.57
$(Ln(GDP))^2$	-0.12	0.01	-11.25	3.12E-19	-0.14	-0.10	1256.42	-5.53









The multiple regression results and inferences for **Model-1** are summarized in the following points:

- Coefficient of determination is 98.2%, which indicates a strong correlation between the carbon dioxide emission, electric power consumption and GDP. 98.2% of variations in emissions is explained by variations in natural log of EPC and natural log of GDP and squared log of GDP.
- Adjusted coefficient of determination is 98.1%, which indicates an excellent goodness of fit.

- Each independent variable namely, Electric Power Consumption (EPC) and Gross Domestic Production (GDP) is a significant predictor of carbon dioxide emission. Also, F-statistic value conveys that the coefficients are significant.
- Natural log of GDP has a positive relationship with carbon dioxide emission. Each unit increase in natural log of GDP will increase emission by 7.08 units.
- EPC and natural log of GDP squared have weak negative relationship with emission. Changes in these variables have negligible effect on carbon dioxide emissions. For example, a 100 units increase in EPC would cause emissions to decrease by 11 units.
- There is presence of multicollinearity among independent variables as indicated by Variance Inflation Factor (VIF) values.
- Residuals are not normally distributed as indicated by histogram and Q-Q plot. Also, Shapiro-Wilk test confirmed non-normality of residuals.
- Residuals vs Predicted scatter plot indicates that there is no heteroscedasticity in the model. Breusch-Pagan test rejected this assertion (see Appendix-B) and confirmed presence of heteroscedasticity in the model. Variable transformation to circumvent heteroscedasticity did not result in removal of heteroscedasticity in the model.
- The model does not reject the null hypothesis of Environment Kuznets Curve (EKC) hypothesis and indicates that economic growth initially degrades the environment; and after reaching its peak, it turns downwards assuming economic growth improves the environment.[1]

Model 2: Relationship of Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI on CO2 emission [2,3,4,5,6].

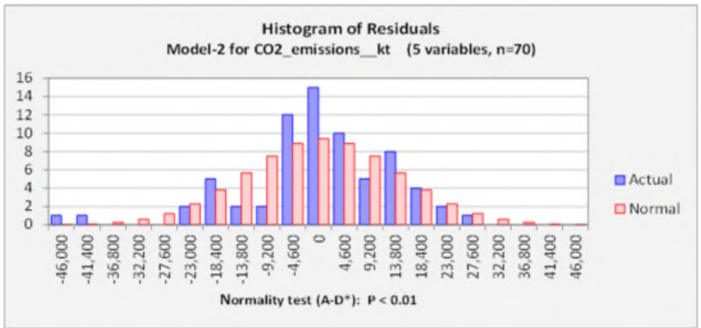
$$CO2\ Emission = 144147 + 9058 Env\ Pol + 1.73 * 10^{-7} GDP + 3.39 Elec\ Cons - 1878 RE\ Cons - 215.57 FDI$$

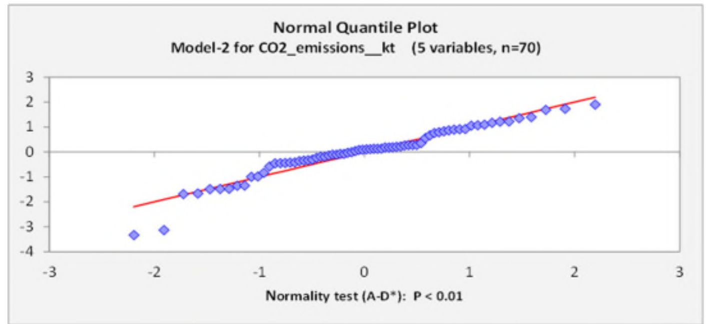
Regression Statistics	
R-Squared	0.986
Adj.R-Sqr.	0.985
Std.Err.Reg.	14135.04
Std.Dep.Var.	116237.03
# Fitted	70
# Missing	50
Critical t	2.00
Confidence	0.95

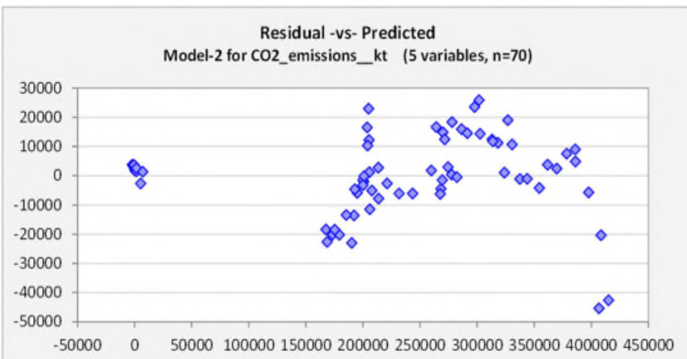
ANOVA			
Source	**Regression**	**Residual**	**Total**
Deg. Freedom	5	64	69
Sum Squares	9.19475E+11	12787166089	9.32E+11
Mean Square	1.83895E+11	199799470.1	-
F-Statistic	920.3979322	-	-

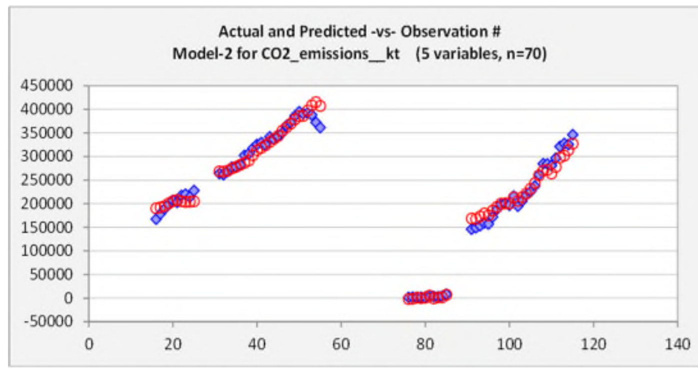
Variable	Coefficient	Std.Err.	t-Statistic	P-value	Lower95%	Upper95%	VIF	Std. Coeff.
Constant	144147.37	5626.86	25.62	2.37E-35	132906.42	155388.31	0.000	0.000
Env Pol	9058.10	1695.59	5.34	1.3E-06	5670.77	12445.43	1.338	0.090
Elec Cons	3.386	0.678	4.995	4.8E-06	2.032	4.740	2.750	0.121
FDI	-215.167	313.072	-0.687	0.494	-840.601	410.266	1.849	-0.014
GDP	1.73E-07	8.65E-09	2.01E+01	2.67E-29	1.56E-07	1.91E-07	3.535	0.552

ReCons	-1878.092	90.618	-20.725	4.34E-30	-2059.123	-1697.061	2.327	-0.463









The multiple regression results and inferences for **Model-2** are summarized in the following points:

- Coefficient of determination is 98.6%, which indicates a strong correlation between the carbon dioxide emission, electric power consumption and GDP. 98.4% of variations in emissions is explained by variations in the independent variables.
- Adjusted coefficient of determination is 98.5%, which indicates an excellent goodness of fit.
- Each independent variable namely, Environment Policy Rating, Electric Power Consumption (EPC), Renewable Energy Consumption and Gross Domestic Production (GDP) is a significant predictor of carbon dioxide emission except Foreign Direct Investment (FDI). Also, F-statistic value conveys that the coefficients are significant.
- Environment Policy Rating, GDP and Electric Power Consumption have strong positive relationship with carbon dioxide emission.
- Renewable Energy Consumption has strong negative relationship with emission. For example, a unit increase in RE Consumption would cause emissions to decrease by 1878 units.
- There is presence of multicollinearity among independent variables as indicated by Variance Inflation Factor (VIF) values.
- Residuals are not normally distributed as indicated by histogram and Q-Q plot. Also, Shapiro-Wilk test confirmed non-normality of residuals.
- Residuals vs Predicted scatter plot indicates that there is no heteroscedasticity in the model. Breusch-Pagan test rejected this assertion (see Appendix-B) and confirmed presence of

heteroscedasticity in the model. Variable transformation to circumvent heteroscedasticity did not result in removal of heteroscedasticity in the model.

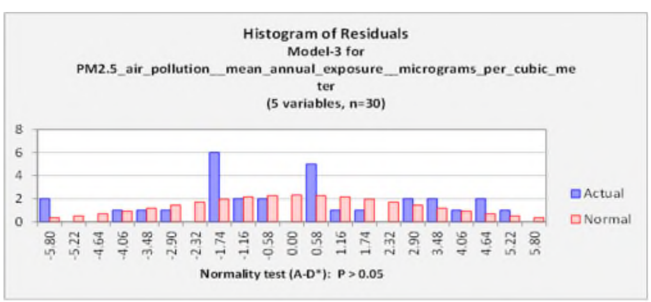
Model 3: Relationship of Environment Policies, GDP, Electricity Consumption, Renewable Energy Consumption, FDI on Air Quality [2,3,4,5,6].

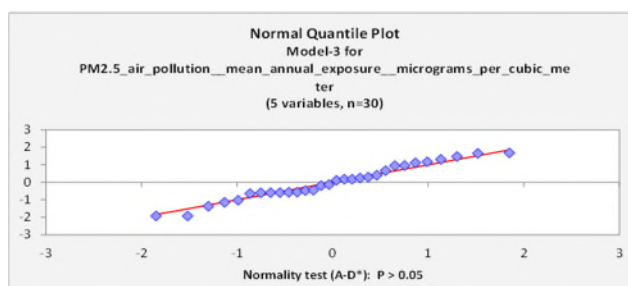
$$Air\ Pollution = 71.62 + 6.3Env\ Pol - 2.25 * 10^{-11}GDP - 0.0045Elec\ Cons - 0.712RE\ Cons - 0.124FDI$$

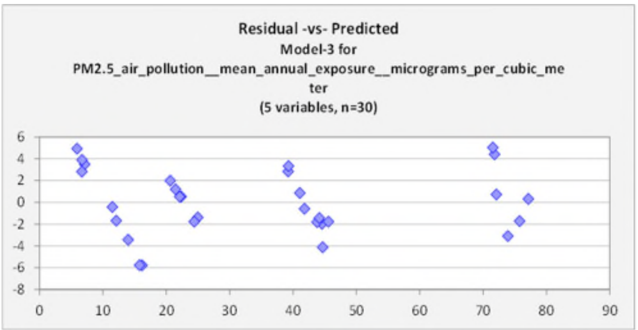
Regression Statistics	
R-Squared	0.984
Adj.R-Sqr.	0.981
Std.Err.Reg.	3.289
Std.Dep.Var.	23.669
# Fitted	30
# Missing	90
Critical t	2.064
Confidence	95.00%

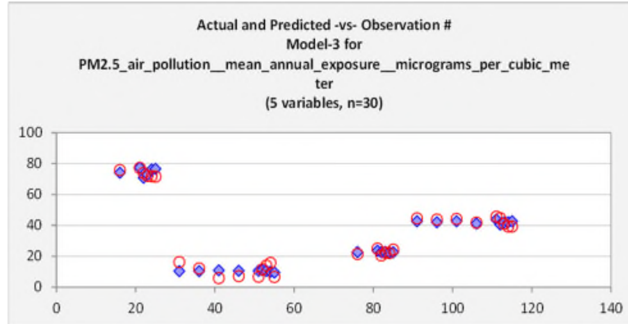
ANOVA			
Source	**Regression**	**Residual**	**Total**
Deg. Freedom	5.000	24.000	29.000
Sum Squares	15986.735	259.680	16246.415
Mean Square	3197.347	10.820	-
F-Statistic	295.503	-	-

Variable	Coefficient	Std.Err.	t-Statistic	P-value	Lower95%	Upper95%	VIF	Std. Coeff.
Constant	71.623	1.977	36.225	1.8E-22	67.543	75.704	0.000	0.000
EnvPol	6.296	0.606	10.388	2.33E-10	5.045	7.547	1.257	0.301
ElecCons	-0.005	0.000	-17.680	2.88E-15	-0.005	-0.004	2.910	-0.778
FDI	-0.124	0.098	-1.267	0.217	-0.326	0.078	2.937	-0.056
GDP	-2.25E-11	0.000	-8.542	9.7E-09	0.000	0.000	3.620	-0.419
RECons	-0.712	0.034	-20.838	7.14E-17	-0.782	-0.641	3.408	-0.993









The multiple regression results and inferences for **Model-3** are summarized in the following points:

- Coefficient of determination is 98.4%, which indicates a strong correlation between the carbon dioxide emission, electric power consumption and GDP. 98.4% of variations in emissions is explained by variations in natural log of EPC and natural log of GDP and squared log of GDP.
- Adjusted coefficient of determination is 98.1%, which indicates an excellent goodness of fit.
- Each independent variable namely, Environment Policy Rating, Electric Power Consumption (EPC), Renewable Energy Consumption and Gross Domestic Production (GDP) is a significant predictor of air pollution except Foreign Direct Investment (FDI). Also, F-statistic value conveys that the coefficients are significant.
- Environment Policy Rating has positive relationship with air pollution.
- Renewable Energy Consumption, GDP and Electric Power Consumption have weak negative relationship with emission.
- There is presence of multicollinearity among independent variables as indicated by Variance Inflation Factor (VIF) values.
- Residuals are not normally distributed as indicated by histogram and Q-Q plot. Also, Shapiro-Wilk test confirmed non-normality of residuals.
- Residuals vs Predicted scatter plot indicates that there is no heteroscedasticity in the model. Breusch-Pagan test confirmed this assertion (see Appendix-B) and we can say that there is absence of heteroscedasticity in the model.

6. <u>Implications and Conclusion:</u>

Carbon dioxide emissions and air pollution are some of the prominent factors attributed to the degradation of environment. The continuous economic growth, energy consumption and lack of appropriate environment policies is worsening the environment and thus resulting in climate change, loss of life, natural disasters, economic loss, and other deleterious problems.

In our study, we try to establish a relation between the carbon dioxide emissions/air pollution and gross domestic production (GDP), electric power consumption (EPC), renewable energy consumption, foreign direct investment (FDI) and environment sustainability policy rating using multivariate linear regression in a panel of countries chosen by income level categories of Low Income, Lower Middle, Middle and High

Income. The replication model (Model-1) [1] would try to confirm the Environment Kuznets Curve (EKC) hypothesis. Other two models (Model-2&3) try to predict carbon dioxide emissions and air pollution from the predictors GDP, EPC, renewable energy consumption, FDI and environment policy rating.

Model-1 results confirmed the Environment Kuznets Curve (EKC) hypothesis for the four (4) countries and we can infer that when economic growth reaches its turning point, increases in per capita income leads to environmental improvements [1].

Model-2 results confirm that Environment Policy Rating, Electric Power Consumption (EPC), Renewable Energy Consumption and Gross Domestic Production (GDP) have a significant contribution to carbon dioxide emissions and Foreign Direct Investment (FDI) does not affect the emissions.

Model-3 results confirm that Environment Policy Rating, Electric Power Consumption (EPC), Renewable Energy Consumption and Gross Domestic Production (GDP) have a significant contribution to air pollution and Foreign Direct Investment (FDI) does not affect the air pollution.

In this study we have learned that Environment Policies are misleading if they are not backed by effective implementation on the ground level, good governance, environment watchdogs, less corruption, etc. which were not established in previous works on the same topic. Decoupling economic growth and human wellbeing from resource use has, therefore, to be an integral part and prime concern of climate policy.

The key takeaway from this study is that a relationship which is established based on the results from analysis of data can be misleading if the underlying assumptions and data collection method are not taken into consideration. For example, a war-torn country would give inaccurate data for the war period and would lead to wrong conclusions.

The major limitations in this study are the violation of linear regression assumptions of normal residuals and homoscedasticity. Since, the results from all of our models suggest that the residuals are not normal, presence of multicollinearity and there is heteroscedasticity in the model (except Model-3). The inferences that we make from the study could be more trustworthy, if we mitigate all these problems in our models.

In conclusion, our study meets the objective of investigating how carbon dioxide emission and air pollution are influenced by different factors and what should be a country's future strategy to counter the challenges posed by environmental degradation. The results from the study come with some caveats that requires mitigation as a part of future work in order to make the results more trustable. Future work would address these limitations and would likely improve the accuracy of the results.

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[12] https://www.theguardian.com/environment
[13] https://data.worldbank.org/
[14]https://www.euractiv.com/section/climate-environment

Appendix A:

Variable Name	Variable Type	Description	Source
CO2 emissions (kt)	Continuous, Ratio	Carbon dioxide emissions are those stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring.	https://databank.worldbank.org/ https://data.oecd.org
Electric power consumption (kWh per capita)	Continuous, Ratio	Electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution, and transformation losses and own use by heat and power plants.	https://databank.worldbank.org/ https://data.oecd.org
GDP (constant 2010 US$)	Continuous, Ratio	GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in constant 2010 U.S. dollars. Dollar figures for GDP are converted from domestic currencies using 2010 official exchange rates.	https://databank.worldbank.org/ https://data.oecd.org

Foreign direct investment, net inflows (% of GDP)	Continuous, Ratio	Foreign direct investment are the net inflows of investment to acquire a lasting management interest (10 percent or more of voting stock) in an enterprise operating in an economy other than that of the investor. It is the sum of equity capital, reinvestment of earnings, other long-term capital, and short-term capital as shown in the balance of payments. This series shows net inflows (new investment inflows less disinvestment) in the reporting economy from foreign investors, and is divided by GDP.	https://databank.worldbank.org/ https://data.oecd.org
Renewable energy consumption (% of total final energy consumption)	Continuous, Ratio	Renewable energy consumption is the share of renewable energy in total final energy consumption.	https://databank.worldbank.org/ https://data.oecd.org

CPIA policy and institutions for environmental sustainability rating (1=low to 6=high)	Continuous, Ordinal (Index)	Policy and institutions for environmental sustainability assess the extent to which environmental policies foster the protection and sustainable use of natural resources and the management of pollution.	https://databank.worldbank.org/ https://data.oecd.org
PM2.5 air pollution, mean annual exposure (micrograms per cubic meter)	Continuous, Ratio	Population-weighted exposure to ambient PM2.5 pollution is defined as the average level of exposure of a nation's population to concentrations of suspended particles measuring less than 2.5 microns in aerodynamic diameter, which are capable of penetrating deep into the respiratory tract and causing severe health damage. Exposure is calculated by weighting mean annual concentrations of PM2.5 by population in both urban and rural areas.	https://databank.worldbank.org/ https://data.oecd.org

Appendix B:

Breusch-Pagan Test:

H0: Model exhibits homoscedasticity.

Ha: Model exhibits heteroscedasticity.

Output from R is pasted below for the three models (Model-1,2&3)

```
> bptest(Model_1)

        studentized Breusch-Pagan test

data:  Model_1
BP = 30.042, df = 3, p-value = 1.352e-06
```

Since, p-value is less than 0.05, the result is significant, hence we reject the null hypothesis.

```
> bptest(Model_2)

        studentized Breusch-Pagan test

data:  Model_2
BP = 16.578, df = 5, p-value = 0.005374
```

Since, p-value is less than 0.05, the result is significant, hence we reject the null hypothesis.

```
> bptest(Model_3)

        studentized Breusch-Pagan test

data:  Model_3
BP = 8.6646, df = 5, p-value = 0.1232
```

Since, p-value is greater than 0.05, the result is insignificant, hence we do not reject the null hypothesis.