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Time series analysis of air pollution trends in Kenya using environmental Kuznets curve

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Abstract
Air pollution occurs when harmful or excessive quantities of substances including gases are introduced into Earth's atmosphere. It may cause diseases, allergies and even death to humans; it may also cause harm to other living organisms such as animals and food crops, and may damage the natural or built environment. Both human activity and natural processes can generate air pollution. The study analyzed the relationship between economic growth and environmental degradation with particular reference to carbon emissions and deforestation. Further, the study seemed to determine the effect of economic growth on the Environmental Kuznets Curve in Kenya for the period 1990 to 2018. The analysis was based upon the environmental Kuznets curve (EKC) model that posits an Inverted-U relationship between income per capita and environmental quality. In particular, the study took into account the current process of globalization with the aim of defining the impact of the progressive global economic integration on the relationship between economic growth and environmental degradation.

Past studies confirm that there is an Inverted-U relationship between income growth and carbon emissions, while the relationship result is less clear in the case of forest change. This goes against the hypothesis of the EKC, thus a need to investigate its applicability in the country. A regression analysis was done to establish the relationship between economic activities and per capita growth on environmental degradation in Kenya through forest change. It was realized that there exists a long-run relationship among the variables. The positive sign of GDP and negative sign of GDP2 confirms that EKC hypothesis is supported in the country. There is significant decrease in forest cover with increase in CO2 emission quantity and with one unit increase in forest cover there is decrease of 2.0074 units of CO2.

The study is important especially in the core policy implications that can be drawn from the results of the study in relation to climate change.

Keywords: Time series analysis, GDP, EKC

1. Introduction

The environmental Kuznets curve is a graph that aims to explain the hypothesized relationship between economic growth and the level of environmental quality. It proposes that in the early stages of economic growth, environmental degradation increases due to increased levels of pollution, however beyond a certain level of income per capita, high income levels lead to the improvement of the quality of the environment. This implies that the curve is an inverted U in shape and is graphed by modeling environmental quality as a function of income, Grossman and Krueger (1991). The environment is one of the major pillars of sustainable development, without it most of the activities that we undertake daily, if not all, would be impossible. This is because the environment fulfils development needs by providing us with human, physical and natural capital as well as enhancing intra- and intergenerational equity (Bass 2006).

1.1 Statement of the Problem

The CO2 emissions in Kenya have been rising over the years. The increase may be attributed to the increased electricity supply accelerated growth of up to 9.7 percent in 2015. The energy mix in Kenya has diversified over the years from relying on hydroelectric power, to the development of geothermal which currently contributes to large amount of power to the grid. There is a shift from use of solid fuel at homesteads to adoption of gases and electric sources which has significantly influenced CO2 emissions. Interventions through tree planting as a salvage to the increasing pollution trends steers the core of this study. The study is thus anchored on the need to reduce the environmental effects of economic growth by identifying the existing relationship between environmental degradation and per capita income through forest change in Kenya.

1.2 Objectives of the Study

1.2.1 General Objective

To analyze Air pollution trends in Kenya using Environmental Kuznets curve.

1.2.2 Specific Objectives

1. To analyze air pollution trends in Kenya between 1990-2018 through forest change.
2. To analyze the relationship between GDP, Income per Capita, human Capital, wages and air Pollution trends between 1990-2018 through forest change.
3. To analyze the Environmental Kuznets curve for Kenya between 1990-2018 through forest change.

1.3 Limitations of the study

1. This study is limited to Kenya's GDP, income per capita and gas emissions trends from 1990-2018.
2. The variables are selected basing on data availability.
3. The study used secondary data obtained from World Development Indicators (World Bank, 2018.

1.4 Literature Review

In Kenya, a study was conducted by Kamande (2007) to investigate the relevance of the EKC in environmental conservation. He modelled the relationship using population growth, per capita GDP, per capita carbon emissions and technology data from 1960 – 2006. His study showed no existence of the EKC in Kenya. Another study was conducted by Usama Al-Mulali (2015) to investigate the EKC hypothesis in Kenya using data from 1980 – 2012 and the Autoregressive distributed lag approach was used. This study showed that fossil fuel energy consumption, GDP, urbanization, and trade openness increased air pollution mutually in both the short and long run. Narayan and Narayan (2010) tested the EKC in 43 developing countries, using CO2 emissions as a measure of environmental quality. They based their conclusion on the short run and long run income elasticity, such that if the short run income elasticity is higher than the long run, then it means that a country's CO2 emissions have reduced and therefore the EKC is valid. The study used time series analysis to analyze individual countries and panel data to do the regional analysis. The time series analysis for Kenya revealed that emissions reduce with an increase in income while the panel data analysis indicated that EKC is not applicable in Africa. This shows that studies should focus on individual countries than regions. It may be misleading to draw a conclusion about a country based on the regional results because of individual country heterogeneity.

Using the Autoregressive Distributed Lag Model, Ozturk *et al*. (2016) analysed the applicability of the Environmental Kuznets Curve in Kenya. They used the Narayan and Narayan 2010 approach, citing high multicollinearity in the standard EKC equation, which assumes that environmental quality depends on GDP and GDP squared. The results of the study indicated that the EKC is not present in Kenya and that fossil fuel energy, urbanization, opening up to trade and GDP enhance pollution both in the short run and long run.

2. Research Methodology

2.1 Data Source

The study used annual data from 1990 – 2018. The variables were sourced from the World development indicators (World Bank, 2018)

2.2 Method of Analysis

A study by Ghosh and Dutta (2003) decomposed the relationship between economic growth and the environment by incorporating the variables that capture the underlying causes of the relationship.

As the economy grows, more inputs are needed in production, hence more natural resources are used up. This is known as the scale effect. More output also implies more waste and emissions as by-products which contribute to environmental degradation. It is expected to be a monotonically increasing function of income.

To do so, the study employed a time series data covering the years from 1990 to 2018 collected from World Bank Development Indicators as proposed by the following functional form for the case of Kenya.

$$CO2t = f\,(ECt,\, GDPt, TOt, URt) \qquad (3.0)$$

CO2 in Eq. (1) represents the carbon dioxide emissions per capita in metric tons, while EC is energy consumption of Kenya and GDP is real GDP per capita calculated by the2005 US$ prices, which is taken as an indicator for living standards. In this study, the natural logarithmic form of the CO2 and GDP and EC variables is used. To indicate trade openness which is calculated as the sum of percentage of exports and percentage of imports to GDP as suggested by Ak ın (2014) and Hossain (2011); UR stands for urban population which is measured as the share of urban population in total population and the subscript *t* represents the time period.

The scale effect function was expressed as (Panayotou, 1997)

$$EDt = \beta 0 + \beta 1xt + \beta 2x2t + \varepsilon \qquad (3.1)$$

Where

ED_t – Level of environmental degradation
β – Parameters to be estimated
x_t – GDP per capita
ε – error term to show a stationery series

To find the turning point of income,

$$\gamma = exp(-\beta 1/[2\beta 2]) \qquad (3.2)$$

To capture the composition effect, the study used the industry, agriculture and services sectors as proxies for structural change. The change from agricultural – industrial economies is expected to add to environmental degradation; therefore, coefficients of the industry and agriculture variables are expected to be positive while that of the services variable may be negative seeing to the fact that the services sector may not be pollution intensive. The composition effect may be expressed as:

$$EDt = \alpha ind + \alpha agr + \alpha ser + \varepsilon \qquad (3.3)$$

Where

ED_t – environmental degradation measure

Ind – share of the industry sector in GDP
Agr – share of the agricultural sector in GDP
Ser – share of the services sector in GDP
α – parameter to be estimated
ε – error term

Higher incomes result in increased demand for better environmental quality and it provides resources for investment in environmentally friendly technology. Therefore, people express their desire for environmental conservation based not only on their income levels but also on their rights and freedoms (Eriksson and Persson 2002). According to Marshall and Jugger (2000), policy formulation in any governing system can be influenced by changes in people's preferences. Policy itself has been used in some studies as a measure of how democratic the structure of a government is. The model that relates the level of environmental degradation to a flexible function of per capita income, that covers all three effects is specified as:

$$EDt = a0 + a1xt + a2x2t + a3x3t + a4yt + \varepsilon t \quad (3.4)$$

Where

ED_t- Proxy measure of environmental degradation; CO2 emissions
X_t - Per capita GDP
Y - A vector of other variables that often affect the environment
ε - Error term

3. Data Analysis, Presentation and Interpretation

3.1 Introduction

This chapter presents a brief overview of the data used, results and analysis of this study as set out in the research objectives and methodology, using version 3 of the R-statistical software.
The data employed in the study was converted to factor to enable them to be read in
R software. The study analyzed the Air pollution trends in Kenya using Environmental Kuznets Curve using forest change as proxy.

3.2 Analysis of Air Pollution Trends in Kenya Through Forest Change Between 1990-2018

Regressing CO2 emissions vs forest cover

Table 1: Summary Output of Air Pollution Trends

Summary Output	
Multiple R	0.87387
R Square	0.76365
Adjusted R Square	0.75338
Standard Error	1314.69
Observations	25

There is a high r squared between the variables forest cover and CO2 emission (0.87387). This shows a good fit since the model explains 87.387% of the data.

Table 2: CO2 Emissions and Forest Cover

	Coefficients	Standard Error	t Stat	P-value	Lower 95%	Upper 95%	Lower 95.0%	Upper 95.0%
Intercept	22901.44	1597.589	14.33501	5.89E-13	19596.58	26206.31	19596.58	26206.31
X Variable 1	-0.38043	0.04413	-8.62058	1.16E-08	-0.47172	-0.28914	-0.47172	-0.28914

From the model summary of regressing Forest cover and CO2 emissions, there is a significant decrease in forest cover with increase in the CO2 emission quantity. This is also visually observed in figure 1 below.

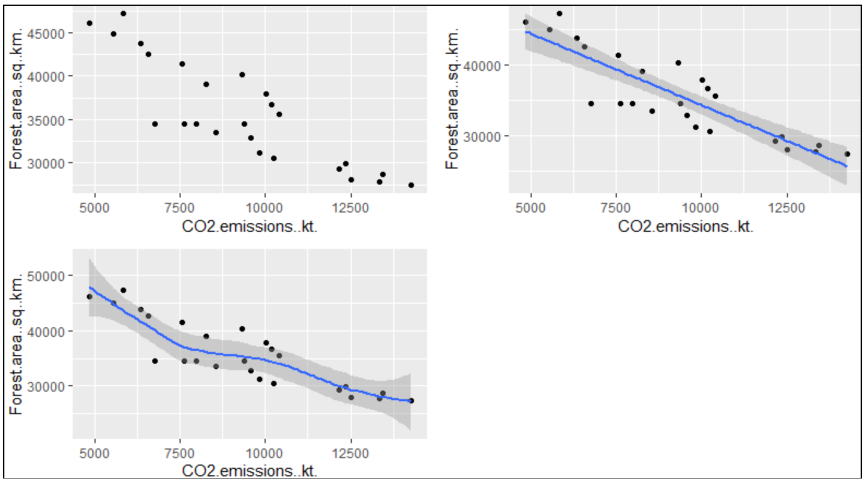

Fig 1: CO2 emissions and forest cover

Table 3: Model Summary

Model Fit										
Fit Statistic	Mean	Min	Max	Percentile						
				5	10	25	50	75	90	95
Stationary R-squared	.753	.753	.753	.753	.753	.753	.753	.753	.753	.753
R-squared	.753	.753	.753	.753	.753	.753	.753	.753	.753	.753
RMSE	1345.066	1345.066	1345.066	1345.066	1345.066	1345.066	1345.066	1345.066	1345.066	1345.066
MAPE	12.282	12.282	12.282	12.282	12.282	12.282	12.282	12.282	12.282	12.282
MaxAPE	42.557	42.557	42.557	42.557	42.557	42.557	42.557	42.557	42.557	42.557
MAE	1067.288	1067.288	1067.288	1067.288	1067.288	1067.288	1067.288	1067.288	1067.288	1067.288
MaxAE	2874.550	2874.550	2874.550	2874.550	2874.550	2874.550	2874.550	2874.550	2874.550	2874.550
Normalized BIC	14.666	14.666	14.666	14.666	14.666	14.666	14.666	14.666	14.666	14.666

Table 4: Model Statistics

Model Statistics						
Model	Number of Predictors	Model Fit statistics	Ljung-Box Q(18)			Number of Outliers
		Stationary R-squared	Statistics	DF	Sig.	
CO2 emissions (kt)-Model_1	1	.753	71.241	18	.000	0

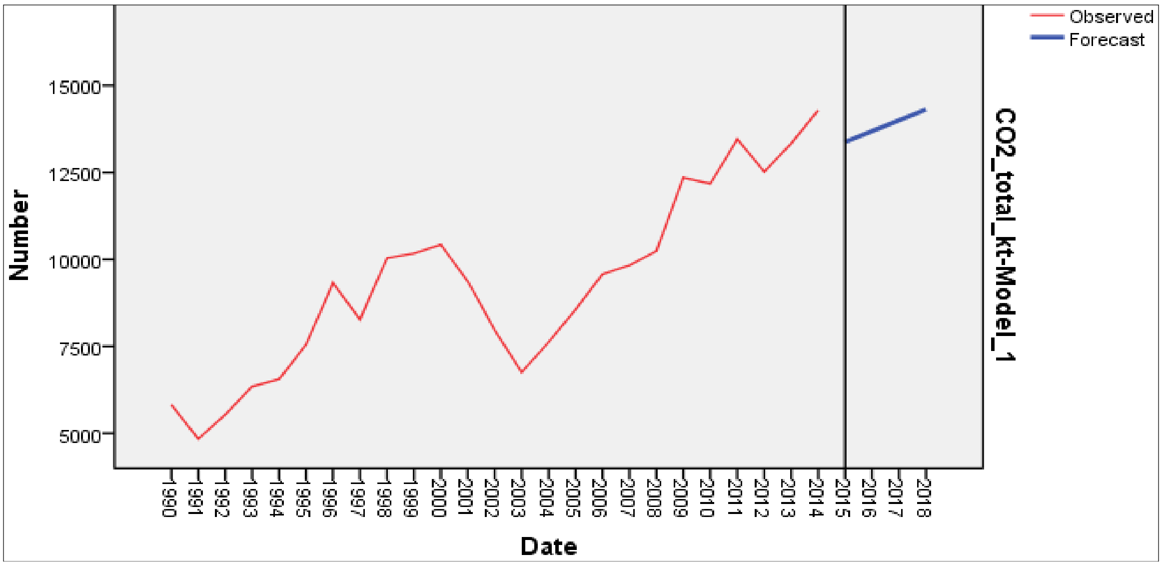

Fig 2: CO2 Forecast

Figure 2 above shows the forecast of the CO2 emissions for an additional 5 years within the confines of the current trend. A significant rise is predicted.

3.3 Analysis of the relationship between GDP, income per capita, human capital, wages and air pollution trends through forest change between 1990-2018

Table 5: Standard Coefficient and Collinearity Statistics

	Standard coefficients			Collinearity statistics	
	Beta	t		Tolerance	VIF
(Constant)		4.538	.000		
Income_per_capita	-2.224	-.655	.520	.000	2047.608
wages_total	-1.265	-3.675	.002	.048	20.992
CO2 emissions (kt)	-.502	-3.204	.004	.229	4.360
GDP per capita (current US$)	3.045	.922	.367	.001	1933.831

From table 7 above, with increase of a unit in forest cover, there is a decrease of income per capita by 2.224 units, decrease in wages by -1.265 units and decrease in co2 emissions by -0.502 units. This practically shows the sense that reduction in forest cover has led to the increase of industrial human activities therefore reduction of forest cover increases the wage, co2 emissions and the income per capita. However, this is depleting of a natural resource.

Table 6: GDP, income per capita, human capital, wages and air pollution trends through forest change model summary

Model Summary[b]									
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.942[a]	.887	.865	2237.259	.887	39.329	4	20	.000

From table 8 above, R squared is 0.887 meaning that the model explains 88.7% of the data rendering it a good fit.

3.4 Analysis of the Environmental Kuznets Curve for Kenya through Forest Change between 1990-2018

Table 7: The Environmental Kuznets summary for Kenya through Forest Change between 1990-2018

Model Summary				
Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.832[a]	.693	.665	1532.942

a. Predictors: (Constant), industry GDP, Agriculture, forestry, and fishing, value added (% of GDP)

Table 9 shows that there's a high correlation between the 2 explanatory variables and CO2 emissions (0.693). This shows that the model fits well.

Table 8: EKC Model Coefficients

Coefficients[a]								
Model		Standardized Coefficients	t	Sig.	95.0% Confidence Interval for B		Collinearity Statistics	
		Beta			Lower Bound	Upper Bound	Tolerance	VIF
1	(Constant)		-5.385	.000	-61961.513	-27507.047		
	Agriculture, forestry, and fishing, value added (% of GDP)	.820	5.067	.000	565.874	1350.012	.534	1.874
	Industry GDP	1.138	7.032	.000	1245.161	2286.851	.534	1.874

a. Dependent Variable: CO2 emissions (kt)

Table 9: Collinearity Diagnostics

Collinearity Diagnostics[a]						
Model	Dimension	Eigenvalue	Condition Index	Variance Proportions		
				(Constant)	Agriculture, forestry, and fishing, value added (% of GDP)	industry_gdp
1	1	2.985	1.000	.00	.00	.00
	2	.015	14.303	.00	.13	.19
	3	.001	57.467	1.00	.87	.81

a. Dependent Variable: CO2 emissions (kt)

3.4.1 Multicollinearity

Variable	VIF
Agriculture. Forestry...and fishing. Value added of GDP.	1.873429
industry GDP	1.873429

From table 10 above we check the last two columns with collinearity statistics. The column of interest is the Variance Inflation Factor (VIF).

Conventionally VIFs greater than 10 are indicators of existing multicollinearity. For this, much attention will not be paid to the tolerance column, since tolerance is the inverse of VIF, therefore doesn't give any new information. In the event that any/some of the values in VIF are greater than 10, then to probe further for the exact pinpointing of the multicollinearity, then we use table 8.

In this case, there appears to be no multicollinearity, since all VIF values are less than 10, as shown in table 9 above. Both are (1.874)

3.4.2 Coefficients

With one unit of increase in CO2 emissions, there is a 0.82 increase in Agricultural GDP while with one increase in CO2 emissions there is a 1.138 increase in industrial GDP share. This shows that in some way shape or form industrial factors are contributors to CO2 emissions by large margins

4. Summary, Conclusions and Recommendations

The study investigated the relationship between CO2 emissions, forest cover and GDP in Kenya between 1990 2018. The result suggests that there exists a long-run relationship among the variables. The positive sign of GDP and negative sign of GDP2 confirms that EKC hypothesis is supported in the country. Increased forest cover decreases CO2 emissions in both short and long run.

The significant existence of EKC shows that the country's effort to reduce CO2 emissions and pursue sustainable development pathways. This indicates the reasonable achievement of controlling environmental degradation in Kenya. The recent launching of the National Climate Change Policy and the National Environmental Policy in 2014 will solidify the country's effort towards sustainable development by reducing emissions. However, findings based on aggregate data may not be able to show the emission patterns of individual regions in the country. It must be emphasized that the implementation of these policies are a necessary but not a sufficient condition. The need for effective enforcement of environmental laws and regulation is paramount not only at the national but also the regional and district levels to prevent the "*pollution haven hypothesis*". Furthermore, research and development activities on environmental degradation which are important to attain sustainable development must be strongly pursued in Kenya.

The study limited the scope of environmental degradation to only the emission of CO2 and forest cover and did not consider other gasses such as nitrogen oxide (NO2), sodium oxide (SO2) and Biochemical Oxygen Demand-BOD (a measure of pollution of water bodies) as a result of data limitations. The data for all the variables of interest in the study retrieved from the World Development Indicators (WDI) database was up to 2018 due to non-availability of data for some variables beyond this period. Further researchers should use regionally disaggregated emissions data to attain a comprehensive impact which will provide new insights to policy makers in controlling degradation at the regional levels.

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