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Modelling the Relationship between Air Pollution and Economic Growth in Somalia

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ABSTRACT

Throughout human history, there has been a clear connection between pollution and the economy. However, the relationship between environmental harm and economic progress is complex, and disagreements between various academic disciplines have made it difficult to understand this phenomenon fully. A unit root test was conducted to gain more insight, which proposed the possibility of further empirical analysis. The Johansen cointegration method was also used to show a long-term connection between air pollution and economic growth. At the same time, the vector autoregressive model (VAR) indicated a short-term connection between the two. A Vector Error Correction Model (VECM) was then employed to estimate the relationship, and the findings confirmed the existence of the environmental Kuznets curve (EKC). The EKC demonstrates that economic growth has positive and negative effects on air pollution. The Granger causality test conducted in Somalia showed a causal link between economic growth and air pollution. The EKC model further supported this finding by demonstrating that economic growth has a statistically significant positive impact on greenhouse gas (GHG) emissions. This implies that Somalia has seen increased GHG emissions, leading to environmental degradation. Therefore, the Somali government must prioritise the implementation of a sustainable energy policy to improve air quality and prevent further environmental deterioration.

Keywords: Air Pollution, EKC, Cointegration Test, VECM, Causality Test, Somalia
JEL Classifications: Q53, C22, C32, O55

1. INTRODUCTION

Considerable discourse has occurred within the scientific and social sciences about the intricate interplay between pollution and economic growth (Jiang et al., 2020). According to Özokcu and Özdemir (2017), the environmental Kuznets curve has obscured certain less apparent connections between economic advancement and environmental consequences. The consideration of the carrying capacity of the ecological system is of utmost importance. Moreover, a significant amount of research is carried out within limited scopes, impeding the opportunity to evaluate an encompassing framework. To progress towards a circular economy, exploring strategies for harnessing pollution as a valuable resource in producing goods is imperative. In regions with lower levels of development, there is a notable rise in pollution levels. Consequently, governmental regulations frequently encounter the obstacle of reconciling divergent perspectives on promoting economic progress and advancing human development. In the absence of more stringent regulations, it is anticipated that air pollution emissions and concentrations will experience a significant increase, thereby presenting a substantial risk to both human well-being and the natural ecosystem. It is anticipated that the adverse health consequences associated with air pollution would lead to substantial economic implications, including considerable yearly global welfare expenses at both regional and sector-specific levels (Jalil and Feridun, 2011).

Air pollution is a global issue affecting the majority of people on the planet. It poses a high risk to human health, exposing individuals to dangerous contaminants exceeding the World Health Organization's recommended limit. Pollution is linked to various illnesses, including lung cancer, respiratory disorders,

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heart disease, stroke, and cognitive decline (Almetwally et al., 2020; Dominski et al., 2021). Furthermore, air pollution has been known to negatively impact agriculture and forest yields through various mechanisms, such as the possible implications of ground-level ozone. This can lead to lower tree growth and survivorship, decreased crop yields, and heightened susceptibility to pests, plant diseases, and other stressors (Dong and Wang, 2023; Rupakheti, 2015).

The air quality in Somalia has experienced a notable deterioration despite the implementation of air quality efforts; the air quality in Somalia is considered moderately unsafe, with an annual mean concentration of PM2.5 of 32 $\mu g/m^3$, which exceeds the recommended maximum of 10 $\mu g/m^3$ according to the World Health Organization's guidelines. Somalia's average annual particulate matter (PM2.5) level is around 3 times higher than the WHO recommended value. This exposure to air pollution causes diseases and adverse health outcomes (TDN, 2021). Over the past decade, the government of Somalia has made notable strides in enhancing its capacity to mitigate environmental damage. An enhanced legislative framework and robust institutional structures have facilitated the advancements described and the implementation of several publicly financed initiatives.

This study examines three primary air pollutants: nitrogen, carbon dioxide, and greenhouse gas emissions. It is worth noting that gasoline contributes to over 60% of the greenhouse effect, with carbon dioxide (CO_2) emissions being the primary culprit (Ozturk and Acaravci, 2010). These emissions mainly originate from the industrial sector, with the automobile industry significantly contributing. However, the industry and the automobile industry are essential in driving economic growth and development (Marjanović et al., 2016). The International Energy Outlook report for 2021 predicts that carbon dioxide (CO_2) emissions related to energy will grow by 34% by 2040, compared to the levels observed in 2012 (EIA, 2021). This increase is primarily due to emerging non-OECD nations relying heavily on fossil fuels to meet their increasing energy needs. The primary purpose of this research is to examine the dynamic correlation between air pollution and economic growth in Somalia. This study will utilise an empirical analytic methodology inspired by the research. The research aims to investigate the relationship between air pollution and economic growth in Somalia, assess the immediate association between air pollutants and GDP, explore the long-term connection between air pollutants and GDP, construct a concise vector error correction model (VECM), and examine the causal impact of air pollution on GDP.

2. LITERATURE REVIEW

Air pollution refers to a wide range of pollutants that come from different sources. According to the World Health Organization (WHO) report from 2023, up to 88% of premature deaths were recorded in low-and middle-income countries, particularly in African nations like Somalia that have limited economic resources. The decline in air quality is a significant environmental concern due to nitrogen dioxide, carbon dioxide, and greenhouse gas emissions that negatively impact human populations. The air pollution concentration is typically higher in metropolitan areas due to increased traffic and population density (Qiu et al., 2019). Kuznets (2019) they conducted research establishing a correlation between economic growth and income disparity in the initial phases. Nevertheless, once the economy surpasses a certain threshold, there is a tendency for income disparity to decrease. In line with the aforementioned logical structure, the environmental Kuznets curve (EKC) theory posits that as economic growth progresses, there will be an initial escalation in environmental stress. However, if a certain threshold is exceeded, further economic growth is expected to help alleviate the environmental strain. This literature portion investigates the causal link between energy use and economic growth. Isik et al. (2018) they examined the relationship between energy consumption and economic growth in the United States, France, Spain, China, Italy, Turkey, and Germany. The researchers found that a causal relationship between renewable energy and economic growth supports the theory of renewable energy-led growth in Spain and growth-led renewable energy in China, Turkey, and Germany. Azam et al. (2019) they studied the relationship between China's energy use, the environment, and economic growth. The study found that energy consumption has a significant positive impact on economic growth. The researchers suggested that policymakers should develop effective policies to promote efficient energy use to encourage sustainable economic growth and development in China.

The matter of air quality holds significant significance in areas characterised by heavy vehicular traffic and industrial operations, particularly in places with restricted geographical dispersion but a high concentration of inhabitants. For instance, Mele and Magazzino (2020) examined the relationship between air pollution and economic growth in China. They found that the relation between steel production is high and causes more air pollution. Magazzino et al. (2021) investigated energy use, economic growth and air pollution in 16 EU countries; they found that energy use, especially electrical energy, increases carbon dioxide emissions, and economic growth also contributes to air pollution problems in 16 EU nations. Moreover, the research findings suggest that pollution primarily arises from the release of emissions stemming from vehicles, industrial operations, and domestic activities.

This study focuses on analysing three specific gases: carbon dioxide (CO_2), nitrogen dioxide (NO_2), and greenhouse gas emissions (GHGs). Gaseous pollutants, such as carbon dioxide (CO_2) and nitrogen dioxide (NO_2), primarily originate from combustion processes involved in heating and transportation. Ground-level nitrogen oxides, known as smog, are frequently observed in atmospheric pollution. The observed phenomena can be attributed to the intricate interplay between solar energy and other contaminants, mainly nitrogen oxides. The objective of this research is to examine the association between the economic prosperity of nations, as measured by gross domestic product (GDP), and their propensity to prioritise the improvement of environmental conditions, commonly referred to as the environmental Kuznets curve (EKC) hypothesis (Tao et al., 2008). The phenomenon of income disparity is characterised by an initial increase that coincides with a nation's economic advancement, followed by a subsequent decrease as the economy grows, ultimately reaching a specific threshold. The environmental

Kuznets curve (EKC) theory posits that a positive relationship exists between economic expansion and environmental pressures, drawing upon similar logical foundations. Nevertheless, it argues that further economic expansion will alleviate the aforementioned environmental difficulties once a specific threshold is surpassed.

The environmental Kuznets curve (EKC) concept Tal Kuznets curve (EKC) proposes a relationship between environmental deterioration and economic growth, demonstrating a distinctive pattern typified by an inverted U-shape. During the transitional phase, it is crucial to emphasise that economic expansion possesses the potential to exacerbate carbon dioxide emissions. However, it is imperative to acknowledge that, beyond a specific threshold, this correlation may undergo a reversal. Therefore, it may be argued that increased economic growth is expected to lead to a progressive reduction in carbon dioxide (CO_2) emissions. Hence, one could posit that economic expansion possesses the capacity to function as a feasible mechanism for achieving a state of enhanced environmental sustainability. The primary objective of this study is to fill an identified gap in the current body of scholarly work by examining the link between greenhouse gas (GHG) emissions and other variables related to air pollution. Moreover, this study aims to analyse the link between pollutant characteristics and the probable ramifications of Somalia's economic growth on these factors. Based on the available information, there appears to be a lack of research replication about this investigation in Somalia.

3. DATA AND METHODOLOGY

3.1. Data

In our study on the relationship between air pollution and economic growth, we analysed the impact of carbon dioxide (CO_2) emissions, nitrogen dioxide (NO_2) levels, and greenhouse gas (GHG) emissions on Somalia's economic growth. Carbon dioxide emissions were measured in kilotons (kt), nitrogen dioxide in micrograms per cubic meter ($\mu g/m^3$), and greenhouse gas (GHG) emissions were measured in tonnes of carbon dioxide equivalent, while economic growth is measured as GDP per capita. We collected secondary time-series data from 1990 to 2020, primarily sourced from the World Development Indicators at the World Bank. The choice of the period is based on the availability of the dataset using the purposive sampling technique.

3.2. Methodology

The quantitative research design of this work incorporated many econometric models, namely the Johansen Cointegration test, the Granger causality test, the vector error correction model (VECM), and the environmental Kuznets curve (EKC) Model. The utilisation of a unit root test, alternatively referred to as a stationarity test, is carried out in conjunction with the vector error correction model (VECM). This involves employing the Johansen cointegration test and the augmented Dickey-Fuller test, as proposed by Dickey and Fuller (1979). However, a subsequent analysis of the statistical methodologies employed will ensue. The underlying principle of the econometrics model posits that the time series data should exhibit stationarity for the vector error correction (VEC) model to be applicable. Additionally, the variables involved should demonstrate stability and provide evidence of cointegration. The VECM utilises a vector autoregressive model that emphasises endogenous variables and allows for the inclusion of lagged values of order p for the model's variables.

The VAR model denoted by VAR (p) is mathematically expressed in a general term below as

$$Y_t = c + A_1 Y_t - 1 + A_2 Y_t - 2 + \ldots\ldots + A_p y_t - P + et \tag{1}$$

(Gujarati, 2009) and the corresponding VEC model can be written as

$$\Delta y_{1,t} = \alpha_1 (y_{2,t} - 1 - \beta y_{1,t} - 1) + \varepsilon_{1,t} \tag{2}$$

Represent GDP as endogenous and its lag values.

$$\Delta y_{2,t} = \alpha_1 (y_{2,t} - 1 - \beta y_{1,t-1}) + \varepsilon_{2,t} \tag{3}$$

Represent GHG emission as endogenous and its lag values.

$$\Delta y_{3,t} = \alpha_1 (y_{2,t} - 1 - \beta y_{1,t-1}) + \varepsilon_{3,t} \tag{4}$$

Represent Nitrogen Dioxide as endogenous and its lag values.

$$\Delta y_{4,t} = \alpha_1 (y_{2,t} - 1 - \beta y_{1,t} - 1) + \varepsilon_{4,t} \tag{5}$$

Represent Carbon dioxide and its lag values.

Where A_1 to A_p are the coefficients of the lag values, Y_{t-1} to Y_{t-p} are the corresponding Lag values, e_t, $\mathcal{E}_{1,t}$ to $\mathcal{E}_{3,t}$ is the error term that takes care of all the unaccounted factors in the model (Hill et al., 2008).

The vector autoregressive (VAR) model is a statistical model that considers all variables as endogenous and allows them to depend on lagged values. To estimate the VAR model, it is necessary for the series to be stationary of order (1), meaning that they should exhibit stationarity after taking the first difference. Once the series satisfies this condition, the appropriate lag value can be determined, and the model can be fitted. The R-square value needs to be relatively high to ensure the reliability of the VAR model.

3.3. Granger Causality Test

We use the Granger causality test to investigate the causal relationship between variables, focusing primarily on the link between the variables of interest. One way to depict the hypothetical link between X and Y is X producing Y (X→Y) or X being related to Y (X↔Y). This study aims to look into the causal connection between X and Y. In order to look at causality, it also establishes a correlation between each variable.

3.4. EKC Model Structure

The EKC hypothesis can be modelled mathematically as

$$InCO2_t = \beta_0 + \beta_1 InGDP_t + \beta_2 (InGDPit)^2 + \varepsilon t \tag{6}$$

$$InNO2_t = \beta_0 + \beta_1 InGDP_t + \beta_2 (InGDPit)^2 + \varepsilon t \tag{7}$$

$$InGHG_t = \beta_0 + \beta_1 InGDP_t + \beta_2 (InGDPit)^2 + \varepsilon t \tag{8}$$

(Özokcu and Özdemir, 2017)

Moreover, it can be diagrammatically explained below.

In order to comprehend the correlation between environmental quality and economic indicators such as income or GDP, the EKC framework proposed by (Tao et al., 2008) might be employed. The diagram depicted above illustrates a typical depiction of the inverse U-shaped hypothesis. The main aim of this study is to investigate the phenomenon of environmental deterioration in Somalia, with a particular focus on the emissions of carbon dioxide, nitrogen dioxide, and greenhouse gases (GHGs). The study used the environmental Kuznets curve (EKC) model, with the dependent variable being environmental degradation indices, as mentioned above. The primary factor being examined in this model is Somalia's gross domestic product (GDP), which serves as the independent variable.

In the early stages of economic development, a direct relationship exists between an individual's income and wealth. The degree of specialism gradually increases until it hits a discernible threshold, generally known as the turning point. A correlation exists between long-term economic expansion and a diminished per capita environmental degradation rate. These phenomena can be observed in the previously described standard environmental Kuznets curve (EKC) Figure 1. Examining the relationship between per capita environmental degradation and per capita wealth, as shown by the environmental Kuznets curve (EKC), provides insights into the sustainability of degradation levels in the context of significant wealth. The environmental Kuznets curve (EKC) suggests a curvilinear association exists between economic progress and environmental degradation, characterised by an initial increase in degradation followed by a subsequent decrease. Initially, the impact of economic activity on the resource base typically results in a limited quantity of biodegradable pollution. The process of industrialisation, particularly in sectors such as agriculture and other extractive and industrial activities, significantly increases resource depletion and waste generation. This growth occurs at a progressively faster pace. In the later stages of development, information-intensive industries and services undergo structural changes, reducing environmental pollution. The implementation of stricter environmental regulations and a rise in costs accompany this. Conversely, in less developed stages, the gradual discharge of pollutants occurs, leading to an acceleration and subsequent plateauing of environmental pollution levels. Based on a study conducted by Panayotou (1993), after accurately identifying the specific problem area with the aid of IT professionals and technicians, some economists contend that the only way to improve environmental quality is through economic growth, assuming the validity of the environmental Kuznets curve (EKC) hypothesis. Rehdanz and Maddison (2008) assert that attaining wealth is the primary and potentially sole method for establishing a positive environment. Environmental factors, in conjunction with affluence, substantially influence various facets of human existence. Before moving on, it is crucial to depict several environmental degradation indicators thoroughly. A wide range of pollutants are produced due to economic activity and consumption. The inclusion of gaseous substances, including carbon dioxide (CO_2), nitrogen dioxide (NO_2), and greenhouse gases (GHG), is essential in this context.

Table 1: Variable measurement

Variables	Measurement	Sources
Carbon dioxide	Kilotons	Macrotrends.net
Nitrogen dioxide	Metric tons	Knoema.com, ceicdata.com
Greenhouse gas	Kilotons	Macrotrends.net
GDP	Billion USD	Macrotrends.net

GDP: Gross domestic product. Source: Macrotrends.net, Kneoma.com, Ceicdata.com.

Table 2: Summary statistics

Variables	Mean	Standard deviation
GDP	24.308	13.322
Carbon dioxide	612.682	59.212
Nitrogen dioxide	8012.097	3051.393
Greenhouse gas	24989.27	1536.455

GDP: Gross domestic product. Source: Author\s computation using STATA software

The most significant value of the indicator for environmental deterioration (E) occurs at the income level (Y*) given as $Y^* = exp(\frac{-B_1}{2B_2})$ The phenomenon being discussed is often known as the Kuznets Phillips curve, also called the environmental Kuznets curve (EKC). In addition, it is vital to conduct essential diagnostic tests such as assessing normality and autocorrelation to ensure the fitted model's robustness, validity, and reliability (Table 1).

4. RESULTS AND DISCUSSION

This section will present the results of the analysis that will satisfy the objective of the study and the discussion of notable findings.

4.1. Results

One can observe from the data that the average economic growth in Somalia between 1990 and 2020 was approximately 24 billion USD, with a variability of about 13 billion USD. Similarly, Somalia's average carbon dioxide emissions during the same period were approximately 613 Kiloton, with a variability of about 59 Kiloton. Additionally, the average nitrogen dioxide emissions during the period under review were about 8012 metric tons, with a variability of about 3052 metric tons. Lastly, Somalia's average greenhouse gas (GHG) emissions were approximately 24989 Kiloton, varying from about 1536 Kiloton (Table 2).

According to the findings presented in Table 3, it is evident that the variables of GDP, Nitrogen Dioxide, and greenhouse gas emissions exhibit a statistically significant level of $P < 0.01$. This suggests that these variables achieve stationarity after undergoing first-order differencing or integration at a 1% significance level. On the other hand, the variable of carbon dioxide emission demonstrates a statistically significant level of $P < 0.05$, indicating that carbon

Table 3: Unit root test with Augmented Dickey fuller test (ADF)

Variables	T-statistic	P-value	Order
GDP	−5.354	0.0001	I (1)
Carbon dioxide	−3.261	0.0264	I (1)
Nitrogen dioxide	−5.365	0.0001	I (1)
Greenhouse gas	−4.704	0.0008	I (1)

GDP: Gross domestic product, Source: Author\s computation using Eviews software emission achieves stationarity. This implies that additional empirical analysis can be conducted given the stationarity of the series.

Table 4 demonstrates the statistical significance of both the trace and maximum eigenvalue tests at a 5% significance level. Specifically, the trace statistic (90.2866) exceeds the critical value (47.21), indicating the cointegration between air pollution and GDP, which indicates economic growth. This finding suggests a long-term association between air pollution and GDP in Somalia. Given the presence of cointegration, it is advisable to employ both short-run modelling, such as the vector autoregressive (VAR) model, and long-run modelling, such as the vector error correction model (VECM).

Based on the results of the VAR model presented in Table 5, it is evident that all the variables included in the model, including their lagged values, exhibit statistical significance at a 1% level. This is indicated by the P-values associated with these variables are <0.01. Consequently, these findings suggest a strong association between air pollution and GDP in Somalia in the short run. The present analysis shows that the R-square value exhibits a considerable magnitude, indicating that the VAR model, specifically the vector autoregressive model, is suitable for accurately representing the data.

According to the findings presented in Table 6, it is evident that the total P-value for the vector error correction model (VECM) is <0.01. This indicates that the fitted VECM exhibits statistical significance at a 1% level. Furthermore, this outcome suggests a long-term association between air pollution and economic growth in Somalia.

From Table 7, we can see that GDP causes all with P = 0.020<0.05which tells us that GDP has a causal effect on the three air pollutants under this study. Individually, Table 6 reveals that Greenhouse gas emission has a causal effect on GDP in Somalia (P = 0.003), CO_2 has a causal effect on the GDP (P = 0.000), and NO_2 also has a causal effect on the GDP (P = 0.000) which suggest that air pollution have a causal effect on the economic growth of Somalia.

Table 8 shows a significant relationship between economic growth and carbon dioxide emissions at a 5% significant level since the overall regression P = 0.0474<0.05. Besides, the economic growth measured by InGDP and $InGDP^2$ has both negative and positive significant effects on carbon dioxide since their P = 0.015<0.05, β = −0.2074 and P = 0.021<0.05, β = 0.042, respectively, supporting the work of Kuznets (2018).

Based on the data shown in Table 9, it is evident that a statistically significant association exists between economic growth and nitrogen dioxide at a 1% level of significance. This conclusion is supported by the overall regression analysis, which yields a P = 0.000, indicating a significance level lower than 0.01. Furthermore, it is worth noting that the impact of economic growth, as measured by $InGDP^2$, on Nitrogen Dioxide is statistically significant and negative. This is evident from the obtained results, where the P-value (P) is 0.004, less than the predetermined significance level of 0.01. Additionally, the coefficient (β) associated with this relationship is −0.1096.

Based on the data presented in Table 10, it is evident that a statistically significant association exists between economic growth and greenhouse gas emissions at a significance level of 1%. This conclusion is supported by the overall regression analysis,

Table 4: Johansen Cointegration

Johansen tests for cointegration Number of Obs=29, Trend: Constant Number of lags=2					
Maximum rank	Parameters	LL	Eigenvalue	Trace statistic	Critical value (5%)
0	20	−640.823	-	90.287	47.21
1	27	−618.436	0.786	45.512	29.68
2	32	−605.253	0.597	19.146	15.41
3	35	−596.808	0.441	2.256*	3.76
4	36	−595.680	0.075		

Source: Author\s computation using STATA software

Table 5: Vector autoregression model (short run)

Equation	Parameters	RMSE	R-squared	Chi-square	P>Chi-square
GDP	9	4.28868	0.9149	311.8854	0.0000
CO_2	9	11.6541	0.9659	821.3979	0.0000
NO_2	9	350.201	0.9900	2885.199	0.0000
GHG	9	480.31	0.9217	341.465	0.0000

GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Table 6: Vector error-correction model

Equation	Parameters	RMSE	R-squared	Chi-square	P>Chi-square
D_GDP	6	5.02139	0.0898	2.268881	0.8934
D_CO_2	6	15.8503	0.5678	30.21985	0.0000
D_NO_2	6	353.15	0.9493	430.9406	0.0000
D_GHG	6	622.763	0.4575	19.3991	0.0035
Overall P>Chi-square=0.0000					

GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software which yields a P = 0.0001, indicating statistical significance at a level lower than 0.01. Moreover, the analysis reveals a noteworthy and affirmative relationship between greenhouse gas emissions and economic growth, as indicated by the statistical significance of the coefficient estimates. Specifically, the P = 0.039, which is less than the conventional threshold of 0.05, suggests that there is a significant impact. The estimated coefficient, = 0.0199, further supports this finding. Consequently, it can be inferred that Somalia has experienced an escalation. However, this enhances the research conducted by Jiang et al. (2020).

4.2. Diagnostic Test

According to the data presented in Table 11, the observed P-value is more than 0.05. This finding suggests that autocorrelation issues do not affect the fitted empirical models. In addressing autocorrelation issues, it is noteworthy to acknowledge the robustness of both the VAR model and VECM.

Table 12 shows the standard quality test using Shapiro-Wilk. The P-values are more remarkable than the 0.05 significant level (P > 0.05), implying that the variables are normally distributed, which satisfies the normality condition and makes the empirical models more valid and reliable.

Figure 2 shows that the gross domestic product, which measures economic growth, has the most minor growth with a constant pattern when compared to the air pollutants, such as greenhouse gas emissions, which have the highest growth patterns, nitrogen Dioxide and carbon dioxide. This means that Somalia's economy has suffered meager economic growth, an indication of a low-income level with a high level of environmental pollution, and there is a need for her government to come up with sustainable policies that will mitigate the excessive pollution as well as improve the economic growth.

4.3. Discussion of Findings

The subsequent discussion will present the key conclusions from this research study.

The findings in Table 3 show that the variables of GDP, nitrogen dioxide, and greenhouse gas emissions exhibit stationarity after undergoing the first difference or being integrated of order 1, with a significance level of 1%. On the other hand, the variable of carbon dioxide emission demonstrates stationarity after the first difference but at a slightly higher significance level of 5%. This implies that additional empirical analysis can be conducted due to the stationarity of the series.

Table 4 presents the statistical significance of both the trace and max eigenvalue tests. The trace statistic (90.2866) exceeds the critical value (47.21) at a significance level of 5%. This finding

Table 7: Granger causality test

Equation	Excluded	Chi-square	df	Prob> Chi-square
GDP	--------------------→CO_2	8.8532	2	0.012
GDP	--------------------→NO_2	7.2315	2	0.027
GDP	--------------------→GHG	3.2163	2	0.200
GDP	--------------------→ALL	14.978	6	0.020
CO_2	--------------------→GDP	21.266	2	0.000
CO_2	--------------------→NO_2	14.244	2	0.001
CO_2	--------------------→GHG	1.8847	2	0.390
CO_2	--------------------→ALL	68.753	6	0.000
NO_2	--------------------→GDP	442.53	2	0.000
NO_2	--------------------→CO_2	3.1411	2	0.208
NO_2	--------------------→GHG	0.99712	2	0.607
NO_2	--------------------→ALL	572.35	6	0.000
GHG	--------------------→GDP	11.978	2	0.003
GHG	--------------------→CO_2	11.455	2	0.003
GHG	--------------------→NO_2	6.1696	2	0.046
GHG	--------------------→ALL	19.894	6	0.003

GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Table 8: EKC equation for carbon emission and economic growth

lnCO_2	Coefficient	Standard error	Test-statistic	P-value
lnGDP	−0.207	0.080	−2.58	0.015
lnGDP_2	0.042	0.017	2.44	0.021
Constant	6.623	0.085	77.65	0.000
Prob>F	P=0.0474, R-squared = 0.1957			

EKC: Environmental Kuznets curve GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Table 9: EKC equation for Nitrogen dioxide and economic growth

lnNO_2	Coefficient	Standard error	Test-statistic	P-value
lnGDP	0.184	0.161	1.14	0.265
lnGDP_2	−0.110	0.035	−3.17	0.004
Constant	9.403	0.171	54.88	0.000
Prob>F	P=0.000, R-squared=0.7678			

EKC: Environmental Kuznets curve GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Table 10: EKC equation for Greenhouse gas emission and economic growth

lnGHG	Coefficient	Standard error	Test-statistic	P-value
lnGDP	−0.049	0.043	−1.14	0.263
lnGDP_2	0.0199	0.009	2.16	0.039
Constant	10.082	0.046	220.85	0.000
Prob>F	P = 0.0001, R-squared = 0.4705			

EKC: Environmental Kuznets curve GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Table 11: Autocorrelation test (Lagrange-multiplier test)

Lag	Chi-square	Df	Prob>Chi-square
1	21.7719	16	0.15071
2	16.3196	16	0.43089

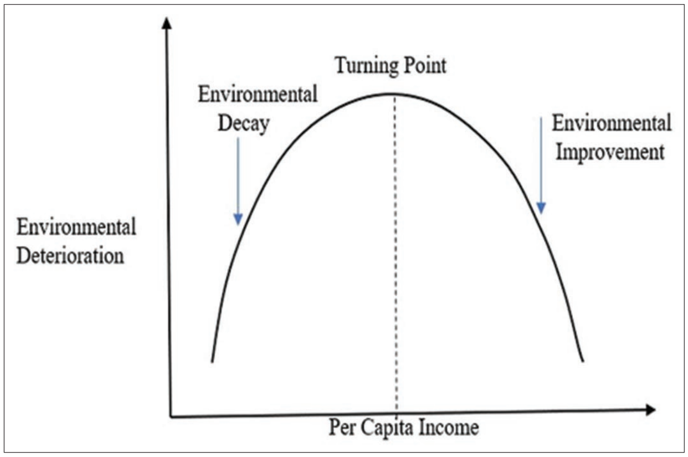
Source: Author\s computation using STATA software

Table 12: Normality test via Shapiro-Wilk

Variables	Observation	P-value
GDP	31	0.88479
CO_2	31	0.96681
NO_2	31	0.96779
GHG	31	0.96779

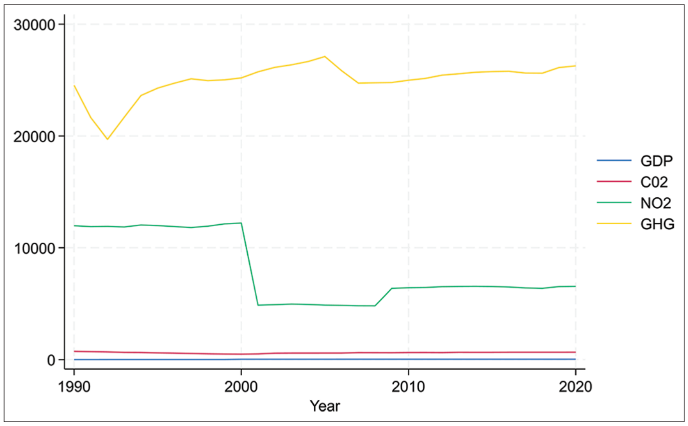
GDP: Gross domestic product, GHG: Greenhouse gas. Source: Author\s computation using STATA software

Figure 1: EKC structure



Source: Adebanjo et al. (2024)

Figure 2: Graph of air pollution and economic growth in Somalia from 1990 to 2020



indicates the presence of cointegration between air pollution and GDP, which serves as a measure of economic growth. Consequently, it can be inferred that air pollution is associated with GDP in Somalia in the long run. Given the presence of cointegration, it is advisable to employ both short-run modelling, such as the vector autoregressive (VAR) model, and long-run modelling, such as the vector error correction model (VECM).

From Table 5, which shows the results of the VAR model, it is clear that all the variables in the model, along with their lag values, are statistically significant at the 1% level. This implies a strong association between air pollution and GDP in Somalia in the short term. The present analysis shows that the R-square value exhibits an enormous magnitude, indicating that the VAR model, specifically the vector autoregressive model, is well-suited for the given dataset.

Based on the data presented in Table 7, GDP exhibits a causal influence on all three air pollutants examined in this study. On an individual basis, the findings presented in Table 6 demonstrate that a causative relationship exists between greenhouse gas emissions and GDP in Somalia. Specifically, it is observed that CO_2 and NO_2 emissions also have a causal impact on the country's GDP. These results suggest that air pollution, as indicated by these emissions, exerts a causal influence on the economic growth of Somalia. Based on the data in Table 8, a statistically significant association between economic growth and carbon dioxide emissions is observed at a significance level of 5%. Moreover, the impact of economic growth, as assessed by InGDP and $InGDP^2$, exhibits positive and negative statistically significant associations with carbon dioxide emissions, corroborating Kuznets's findings (2018).

Furthermore, upon examination of Table 10, it becomes evident that a substantial correlation exists between economic growth and greenhouse gas emissions at a significance level of 1%. This conclusion is drawn from the fact that the total regression is statistically significant. Moreover, a noteworthy positive correlation exists between economic growth and greenhouse gas (GHG) emissions in Somalia. This suggests that the country's economic expansion has increased GHG emissions, contributing to environmental degradation. The rise in GHG emissions is directly proportional to the growth in the country's economy. However, the work of Jiang et al. (2020) has been enhanced by this.

5. CONCLUSION AND POLICY IMPLICATION

The primary objective of this study is to investigate the dynamic relationship between air pollution and Somalia's economic growth through an empirical, analytical approach. The primary objective of this study is to fill the current gap in research by investigating the correlation between greenhouse gas (GHG) emissions and several indicators of air pollution. The research undertaken Jiang et al. (2020) emphasises the lack of enough focus on a particular component in earlier research efforts. Moreover, the main aim of this research is to examine the influence of Somalia's economic expansion on air pollution. This subject has not been previously examined in the specific context of Somalia. The understanding of the complex interplay between economic growth and environmental degradation has been hindered by biases originating from particular academic fields.

The current study utilised a unit root test to assess the viability of further empirical investigation. Furthermore, the Johansen cointegration methodology was employed to determine a sustained relationship between air pollution and economic growth. The vector autoregressive model (VAR) posits a transitory correlation among the variables. Following that, a vector error correction model (VECM) was utilised to estimate the association, and the results substantiated the presence of the environmental Kuznets curve (EKC). Furthermore, the environmental Kuznets curve (EKC) illustrates a significant and dichotomous correlation between economic advancement and air pollution. The use of the Granger causality test within the framework of Somalia demonstrates an observable causal connection between the phenomenon of economic expansion and the occurrence of air pollution. Additionally, the graphic representation in Figure 2 shows a notable pattern with a gradual increase in greenhouse gas (GHG) emissions levels. The environmental Kuznets curve (EKC) paradigm demonstrates a notable positive correlation between economic growth and greenhouse gas (GHG) emissions. This implies that Somalia has witnessed an increase in the emission of greenhouse gases (GHGs), resulting in environmental deterioration inside the country. Hence, the Somali government must accord primacy to implementing a sustainable energy policy to enhance air quality and mitigate environmental deterioration.

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