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Economic Growth and Environmental Pollution in Tanzania: An Environmental Kuznets Curve Analysis

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Abstract

The creation of a long-term linkage between economic growth and environmental protection is a subject of an ongoing discussion among scholars and policymakers. The relationship between environmental quality and economic growth is viewed from two different angles. According to the first, it is impossible to protect the environment and increase the economy at the same time since doing so will inevitably result in the extinction of either one or both. The other contends that economic advancement and higher environmental quality can be achieved simultaneously since increasing economic growth raises income levels, which in turn increases the demand for environmental protection. However, there is a disagreement over how much environmental resources should be exploited to support rapid economic expansion. This study used the approach of the Environmental Kuznets Curve (EKC) hypothesis to investigate the relationship between economic growth and environmental pollution in Tanzania. Tanzania's economy annual data from 1970 to 2018 was used in the ARDL bounds testing for cointegration procedures. The evidence suggests that environmental pollution and economic growth have a U-shaped relationship, which rules out the existence of a traditional EKC in Tanzania. Like in many emerging economies, environmental pollution is anticipated to rise in Tanzania if economic expansion continues beyond a threshold level. The U-shaped link between economic growth and environmental pollution is important for policy formulation because both economic growth and a clean environment are welfare-enhancing; therefore, it is possible to have two policies that are mutually supportive rather than antagonistic. This can be achieved by having a proper environmental, legal, and institutional frameworks.

Keywords: *EKC, economic growth, CO_2 emissions, ARDL model, Tanzania*

Introduction

The growing demand for income and other natural resources for economic expansion leads to an increase in waste production, particularly emissions that have an impact on the environment. Industries are developed by nations as the primary engines of development. However, because of their limited resources (financial and human), and poor technological levels, nations opt for industries that produce a lot of pollution that have detrimental impacts on the environment (Stavropoulos et al., 2018). The natural environment affects economic activities

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directly or indirectly. It directly contributes by providing water, timber, and minerals. These resources are raw materials for goods and services. Ecosystem services include carbon sequestration, nitrogen cycling, water purification, and flood management, which indirectly assist economic activities (Everett et al., 2010).

Academicians and policymakers continue to disagree on how to achieve a sustainable link between economic growth and environmental protection. According to Lee et al. (2021) and Polasky et al. (2019), a sustainable link fosters economic growth while preventing resource depletion, environmental damage, and income instability. The relationship between environmental quality and economic growth is viewed from two different angles. The first—and a more common perspective—claims that environmental protection and economic growth are incompatible since an advancement in one will inexorably result in a deterioration in the other. It also emphasizes the possibility of environmental pollution and loss of human welfare as a result of the extraction of natural resources for economic purposes. Continuous resource exploitation could lead to environmental degradation and waste accumulation, putting the entire economic activity at risk (Bennett et al., 2008; Wolde, 2015). Contrary to the first view, another view suggests that economic advancement and higher environment improvement can be achieved simultaneously (Pettinger, 2021). Higher economic growth increases levels of income, which stimulate greater demand for environmental protection by increasing demand for less materials, intensive goods and services. Additionally, when income levels rise, people spend more money on research and development of manufacturing methods, which result in higher productivity and less environmental harm (Surya et al., 2021). The current debate centres on how much of the environment's resources should be used to support quick economic expansion.

The dilemma is best understood when two opposing schools of thought are taken into account. The proponents of smart growth argue that, to protect the environment, economic development and societal well-being must coexist. Given that the majority of environmental resources are non-renewable, and some of the effects of environmental pollution are long-lasting, environmental resources must be used sustainably to support economic growth. The 'going-for-growth' perspective is another school of thought that emphasizes accelerated economic growth over the development of environmentally sound policies. It holds that environmental regulations may impede economic growth, but economic expansion can benefit both the environment and the economy (Jian et al., 2022; Yang et al., 2022). The recommendation here is that when economies develop, it is necessary to allow them to shift away from environmentally detrimental behaviours. The proponents of this strategy also claim that it is doable to allow initial environmental degradation to stimulate economic growth, and then divert the extra income to environmental management (Ji et al., 2022).

Grossman and Krueger (1995) initiated a discussion on the environmental Kuznets curve hypothesis (EKC) in 1991. According to the EKC hypothesis, there is an inverted U-shaped link between environmental pollution and economic growth. The presumptions of this claim are based on static technology, cultural preferences, and environmental commitments (Wolde, 2015). Thus, it asserts that increased economic activity ultimately harms the environment; and that as income rises and resources become more readily available for investment, there will be an increase in the demand for better environmental quality (Demissew et al, 2020).

Tanzania, like other emerging economies, has recently seen a fast population expansion, a rise in urbanization, a booming economy propelled by the nation's industrialization ambition, and climate change and variability. These patterns are depleting natural resources and making it harder for them to keep delivering goods and services. The poor are disproportionately impacted by environmental pollution, which is threatening economic growth and the quality of life. Rapid economic growth, which is brought on by the liquidation of natural capital, may boost the economy momentarily, but falls short of laying the groundwork for long-term improvement in people's wealth and well-being (World Bank Group, 2019).

Despite the efforts that Tanzania's government has been making to support sustainable economic growth, knowledge about causes, magnitude and effects of economic growth on environmental pollution is still lacking. The fundamental driving force behind this study was the realization that establishing a link between environmental sustainability and economic growth will inform decision-makers and help them formulate the best possible policies in this area. Given that Tanzania is a member of the Kyoto Protocol, the findings of this study have important policy implications for both environmental quality and economic growth. This study offers responses to the following questions: Is there a link between Tanzania's economic growth and environmental pollution? What implications does the relationship between environmental quality and economic growth have for the sustainability of a green economic growth in the country? What is the causal relationship that exists between Tanzania's economic growth and environmental pollution?

The introduction, literature review, methodology, results and discussion, conclusion, and implications are major sections that make up the structure of this article.

Literature Review

Theoretical Literature

The EKC theory posits a long-term relationship between environmental effect—defined in this case as the concentration of carbon dioxide emissions per capita (CO_2 per capita)—and economic growth as measured by GDP per capita. According to the EKC, the level of emissions rises as the revenue of the economy increases over time. As the economy shifts to information-intensive services and industries, and as the environmental consciousness and enforcement rise, the emissions reach a peak at Y* before beginning to decline (Figure 1). The threshold or tipping point for income is known as the turning point (Wolde, 2015).

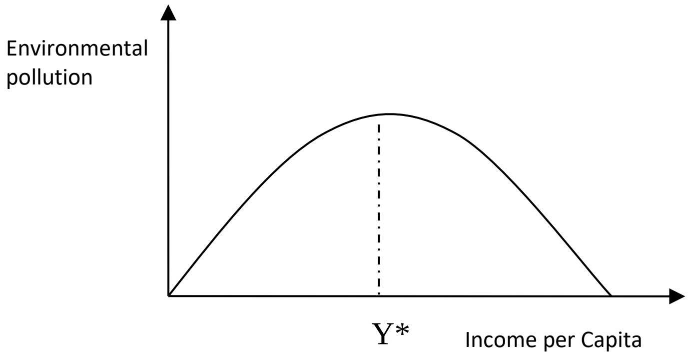

Figure 1: Diagram of the EKC

The theoretical underpinning for the EKC relationship has been provided by different approaches that vary, but all lead to the same conclusion. Usenata (2018) suggests that the theoretical literature underpinning the ECK relationship should be classified into static and dynamic segments. A few researches use a static model method to illuminate the expositions of the EKC hypothesis (Ekins, 1997; Jaeger, 1998; Lopez, 1994; Mallik, 2018). For instance, Lopez (1994) created a model of the relationship between output and pollution, and concluded that consumers had preferences regarding income, output price, and pollution levels.

The other study that used a static technique as a foundation for the ECK relationship was conducted by Jaeger (1998). In this study, the decision between dirty and clean goods was made, and a static general equilibrium model was specified. Jaeger added that the technique effect was also indicated. The study concluded that as income levels rise, the environment transitions from an abundant to a scarce factor, gradually leading agents to choose cleaner products and technology. These flows cause the EKC.

Further, the decision between consumption and investment in pollution reduction was presented in a study by Mallik (2018) using a static-partial equilibrium model. According to this study, more resources will be spent on trying to reduce pollution as income increases. The EKC will arise due to increased returns from technologies that reduce pollution. The static models have shortcomings because they cannot describe decision making and planning in the long-run. This circumstance could lead to incorrect conclusions concerning the precise relationship between environmental pollution and economic growth.

On the other hand, several studies have assessed the theory of the ECK hypothesis utilizing a dynamic model approach (Ansuategi & Perrings, 1999; Jones & Manuelli, 1995; Stokey, 1998). Ansuategi and Perrings described a dynamic infinite, two-country growth model in 1999. In that paradigm, pollution enters the utility and may have consequences beyond borders. Additionally, they specified the pollution abatement effects. This study concluded that the ECK is less likely when transboundary pollution externalities predominate.

The study by Stokey (1998) is another investigation that offers theoretical literature on the ECK hypothesis. A dynamic two-country growth model with an unlimited horizon was specified in this work. Similar to the study by Ansuategi and Perrings (1999), pollution enters utility, and as a by-product of production. This study discovered a critical point at which technology limitations take hold. It concluded that this marks the environmental ECK turning point.

Another study that used a dynamic approach to explain the ECK hypothesis is by Jones and Manuelli (1995). A dynamic overlapping generation model was used in this study, where pollution is a by-product of capital, and enters the utility. The study outlined a pollution tax and a standard paradigm where producers might choose between input efficiency and pollution emissions. They discovered that manufacturers would eventually select less labour-intensive inputs if taxes and requirements were optimal. This situation leads to the ECK.

A U-shaped association between economic growth and environmental pollution is among the other functional forms that have been confirmed, in addition to the original illustration of the inverted U-shaped ecological Kuznets Curve (Cole et al., 1997; de Bruyn et al., 1998; Olusegun, 2009; Shafik, 1994; Shafik and Bandyopadhyak, 1992). Since even countries with the highest incomes are still on the upward-sloping portion of the quadratic function, Cole et al. (1997) contend that adopting a linear function rather than a quadratic form is more suitable.

The N-shaped curve is another function form of association between economic growth and environmental pollution, which has been confirmed. According to de Bruyn et al. (1998), an N-shaped curve is more a product of polynomial curve fitting than a representation of any underlying structural relationship. The second turning point often happens at relatively high per capita income levels, which are only attained by a very small number of countries, assuming an N-shaped pattern is formed.

Empirical Literature

The EKC theory has two empirical strands. The first strand uses panel data to examine economic growth and environmental pollution across countries. Cross-country EKC studies offer conflicting results. Numerous studies support the inverted U-shaped EKC (Demissew Beyene & Kotosz, 2020; Gao & Zhang, 2021; Grossman & Krueger, 1995; Lieb, 2003; Perman & Stern, 1999). Several other investigations have found a linear, N-shaped, or inconclusive correlation; contradicting the EKC theory (Coulibaly, 2016; Ella et al., 2022; Gao & Zhang, 2021; Kasten, 2015). For instance, Grossman and Krueger (1995) studied the environmental impacts of NAFTA using the GEMS dataset. Air quality and economic growth were examined using a cross-section sample of comparable air pollution metrics for urban districts in 42 countries. They found that SO_2 and dark matter (fine smoke) concentrations rise with per capita GDP at low national income levels, but diminish at higher income levels. The study found an inverted U-shaped relationship between SO_2 and dark matter, with turning points between $4,000 and $5,000.

Two cross-countries studies were conducted in Asia to test the existence of the EKC hypothesis. The first study was by Taguchi (2012), which tested the EKC hypothesis using panel data. This study analysed representative environmental indices, including carbon and sulphur emissions from 1950 to 2009, in 19 Asian economies using a GMM. It found that carbon emissions rise with per capita income, but sulphur emissions follow an inverted U-shape pattern. The second was by Gao and Zhang (2021), which studied 13 developing Asian nations. This study investigated CO_2 emissions, biomass energy use, economic growth, and urbanization. They found that CO_2 emissions caused economic growth in the causation test.

Furthermore, the EKC hypothesis was examined by Demissew Beyene and Kotosz (2020) in 12 countries to fit the study. To explore the link between carbon emissions and per capita income as the respective proxy for environmental pollution and economic growth, they used the pooled mean group (PMG) technique. They found a bell-shaped curve link between environmental pollution and economic growth.

Coulibaly (2016) explored the EKC hypothesis in the members nations of the West African Economic and Monetary Union (WAEMU). He created the cubic EKC model using 1970–2010 CO_2 emissions and GDP per capita data. The model included energy consumption, GDP growth, industrial share, and pollution density as control variables. This study found two WAEMU country categories. First, low-income countries had no link between GDP and CO_2 emissions. The other group showed a positive link between GDP and CO_2 emissions, showing they were rising on the EKC. This implies that economic growth and pollution in the WAEMU differ.

Ella et al. (2022) conducted the most recent panel survey in African countries. They investigated the EKC theory for 6 countries in the Economic and Monetary Community of Central African States (CEMAC) to see if changes in per capita GDP impacted environmental quality. The fixed effects model method was used in the investigation. They discovered that although there is no empirical support for the EKC hypothesis, there is an N-shaped association between economic expansion and environmental damage.

The second element of the EKC hypothesis involves country-specific time-series data. According to Lindmark (2002), historical research on specific nations enables a closer analysis of the EKC pattern. Stern et al. (1996) argue that time-series data from a single nation can explain historical events like environmental legislation, trade relations, and exogenous shocks like the oil crisis.

The CO_2 emissions variable has been employed as a stand-in for environmental pollution in most published empirical works. Energy usage is introduced in the model as a control variable. On other hand, GNP, GDP and economic growth rate variables have been used to measure economic growth (Aydin & Esen, 2017; Balıbey, 2015; Chuku, 2011; Fang & Liu, 2011; Kurt et al., 2016; ÖZBEK & Bahar, 2022; Wolde, 2015; Zhang, 2021).

Balıbey (2015) conducted a study in Turkey utilizing time series data from 1974 to 2011. This study revealed the linkages between economic growth, CO_2 emissions, and foreign direct investment (FDI). Additionally, the study used a regression model technique to assess the possibility of the EKC hypothesis. The findings of the study suggested that Turkey's economic progress resulted in environmental harm and depletion of natural resources. However, Aydin and Esen (2017) found no EKC in Turkey's economy. This study tested the EKC hypothesis on the Turkish economy using a smooth transition regression (STR) model. They used the 1971–2014 GDP per capita and CO_2 emissions data. They demonstrated that CO_2 emissions rise with GDP per capita in early development. After that, affluence slows them down; but does not reduce them.

Zhang (2021) examined the link between CO_2 emissions and economic growth, empirically. Energy, trade openness, and urbanization were added as controls. The EKC hypothesis was tested using the ARDL model and bounds test. The study found an N-shaped relationship between CO_2 emissions and GDP per capita. On their part, Chuku (2011) and Wolde (2015) examined the relationship between the economic growth of developing nations and environmental pollution using the EKC approach. Chuku (2011) examined Nigeria's 1960–2008 income-environment interactions using standard and nested EKC models. The basic EKC model found minimal support for the EKC hypothesis. The nested model found an N-shaped income-CO_2 emission relationship. The structural rupture did not affect Nigeria's income-environmental pollution relationship. On the other hand, Wolde (2015) examined economic growth and environmental pollution in Ethiopia using the EKC hypothesis. This study used the 1970–2011 CO_2 emissions and GDP per capita. The dataset was checked for a unit root using the Augmented Dickey-Fuller (ADF) method. The long-term connection between variables was examined using the Johansen-cointegration approach. The study found that Ethiopia demonstrated the EKC hypothesis.

Also, the Autoregressive Distributed Lag (ARDL) bounds testing approach of cointegration has been employed to study the long-term and short-term links between economic growth and environmental pollution (Kurt et al., 2016; Shahbaz, 2012; Villanthenkodath, 2021; Zhang, 2021). Villanthenkodath et al. (2021) examined how economic structure affects ecological quality using the EKC.

The environmental pollution function contained aggregated and disaggregated economic development measures from India from 1971 to 2014. The ARDL bounds testing analysed the long-term and short-term link. Environmental quality and economic growth were found to be U-shaped. This findings supported India's EKC hypothesis. On their part, Kurt et al. (2016) tested the existence of the EKC hypothesis and found a link between pollution and economic growth in Turkey. The EKC was tested for 1960–2015 using data on CO_2 emissions, GDP, energy use, and industrial and service production. To examine long- and short-term variable relationships, they used the Zivot-Andrews unit root test, and the ARDL bounds testing. Environmental pollution and economic growth were found to have an inverse U-shaped relationship.

Most of the reviewed studies employing the EKC approach to investigate the link between economic growth and environmental pollution were carried out in developed nations. Additionally, only a few of these studies used ARDL bounds cointegration testing techniques. This work fills that gap by using ARDL bounds cointegration testing techniques to examine the link between economic growth and environmental pollution in a developing country, specifically Tanzania. Also, the causal direction between economic growth, energy use, and environmental pollution is determined. This study will be used as a source of knowledge for academicians, politicians, and other public and private organizations in establishing policies, projects, and programmes; and building institutions to strike a balance between environmental quality and economic growth.

Methodology

Model Specification

The EKC hypothesis follows an IPAT framework, which was first presented by Ehrlich and Holdren (1971). According to Villanthenkodath (2021), an IPAT is an identity that is used to determine what constitutes the patterns of the environment. It states that an environmental pollution proxy, in terms of emissions (I), is the product of the measures of population growth (P); the wealth of society, mostly given as GDP (A); and technology proxy (T).

$$I = PAT \qquad (1)$$

Equation 1 was criticized because it assumes that all parameters have equal elasticities (Villanthenkodath, 2021; Zhang, 2021). Upon modifying the model in equation 1, Dietz and Rosa (1997) introduced the STIRPAT model as in equation 2:

$$I_t = \omega P_t^{\alpha} A_t^{\beta} T_t^{\gamma} \mu_t \qquad (2)$$

In equation 2, ω indicates the intercept, the elasticities associated to the impact of P; A and T on the environment are represented by α, β, γ, respectively. The term μ_t represents the random error in the model, whereas subscript t represents the respective year.

Kurt et al. (2016) and Villanthenkodath (2021) provided the theoretical underpinning for this investigation. Pollution emissions and economic growth were examined using a modified STIRPAT equation. Kurt et al. (ibid.) introduced the square of GDP per capita, energy use, and industrial and service production per GDP in equation 2. Villanthenkodath (2021) added population and urbanization to the STIRPAT equation. According to Shahbaz et al. (2013), energy utilization (kg of oil equivalent) affects country-level pollution and raises pollutants, which degrade the ecosystem.

Stationarity Test

Non-stationarity is an econometric problem that occurs in most macro-economic variables. Regressing such kind of non-stationary variables can falsely infer the existence of a meaningful relationship. Therefore, this study employed the ADF developed by Dickey and Fuller (1979), and the P-P by Phillips and Perron (1988), to test the stationarity of variables. Because these tests do not consider structural breakpoints in data, they can provide bias and spurious results. Zivot and Andrews (1992) developed a unit root testing procedure that determines structural break in the series internally.

Zivot-Andrews' approach suggests three models to test the stationarity as follows. One-time change in the constant is permitted by the first model (Model 1 in equation (3)):

$$\Delta X_t = \hat{\mu}^1 + \hat{\theta}^1 DU_t + \hat{\beta}^1 t + \hat{\alpha}^1 X_{t-1} + \sum_{i=1}^{k} \hat{\gamma}_i^1 \Delta X_{t-i} + \hat{e}_t \qquad (3)$$

The non-stationary is examined around a broken trend by the second model (Model 2 in equation (4)):

$$\Delta X_t = \hat{\mu}^2 + \hat{\beta}^2 t + \hat{\rho}^2 DT_t^* + \hat{\alpha}^2 X_{t-1} + \sum_{i=1}^{k} \hat{\gamma}_i^2 \Delta X_{t-i} + \hat{e}_t \qquad (4)$$

The chance of a change in the constant or in a broken trend is assessed by the third model (Model 3 in equation (5)):

$$\Delta X_t = \hat{\mu}^3 + \hat{\theta}^3 DU_t + \hat{\beta}^3 t + \hat{\rho}^3 DT_t^* + \hat{\alpha}^3 X_{t-1} + \sum_{i=1}^{k} \hat{\gamma}_i^3 \Delta X_{t-i} + \hat{e}_t \qquad (5)$$

The Zivot-Andrews stationary testing approach assumes that the null hypothesis for equations (3), (4) and (5) is $\hat{\alpha}$ equals to zero. This implies that X_t has a structural break that is non-stationary (Dritsaki & Dritsaki, 2021).

Modelling Strategy

This study utilized the data of CO_2 emission per capita, GDP per capita, and energy use per capita, in examining the existence of EKC for Tanzania's economy.

The general function form of the model is postulated as in equation (6):

$$\Delta C_t = f(E_t, Y_t, Y_t^2, X_t) \qquad (6)$$

Study variables were transformed into natural logarithm following Bese and Friday (2021), Kurt et al. (2016), Shahbaz et al. (2013), and Villanthenkodath (2021). Therefore, the empirical form of the model is given as in equation (7):

$$lnC_t = \beta_1 + \beta_Y lnY_t + \beta_{Y^2} lnY_t^2 + \beta_E lnE_t + +\varepsilon_t \qquad (7)$$

Where lnC_t is natural log of CO_2 emissions per capita, lnE_t is natural log of energy use per capita, and $lnY_t(lnY_t^2)$ is the natural log of GDP per capita (square of GDP per capita). ε_t is the error term assumed to be having normal distribution, with zero mean and predictable variance.

Cointegration Methodology: The ARDL Cointegration

The study used Pesaran et al.'s (2001) ARDL bounds testing approach to cointegration. The ARDL bounds testing for cointegration tests the level relationship between a dependent and a group of regressors. Lagged dependent variable values and current and lagged regressors values are explanatory variables in the model. Unlike the VAR model, it uses both exogenous and endogenous variables, and provides many econometric advantages. First, the model works for I(0), I(1), and mutually cointegrated variables. Second, it works better with tiny and finite sample data. The ARDL (*p, q*) is generally specified as in equation (8):

$$Y_t = \varphi_{0i} + \sum_{i=1}^{p} \alpha Y_{t-i} + \sum_{i=0}^{q} \beta_i' X_{t-i} + \mu_{it} \qquad (8)$$

Where; Y_t' is a vector, variables in $(X_t')'$ are allowed to be purely *I(0)* , *I(1)* or cointegrated. α and β are coefficients, φ is the constant, p and q are associated with the optimal lag orders of the dependent and explanatory variables, respectively, and μ_t is the independent and identically distributed random error.

The ARDL model for this study is specified as:

$$\Delta lnC_t = \varphi_0 + \beta_1 lnC_{t-1} + \beta_2 lnY_{t-1} + \beta_3 lnE_{t-1} + \sum_{i=1}^{p} \alpha_{1i} \Delta lnC_{t-i} + \sum_{i=1}^{q} \alpha_{2i} \Delta lnY_{t-i} + \sum_{i=1}^{q} \alpha_{3i} \Delta lnE_{t-i} + \beta_4 dum + \mu_t \qquad (9)$$

Pesaran et al. (2001) suggested an F-test for the joint significance of lagged-level variable coefficients. The null hypothesis ($H_0: \beta_1 = \beta_2 = \beta_3 = 0$) against the alternative hypothesis ($H_1: \beta_1 \neq \beta_2 \neq \beta_3 \neq 0$) claims that there is no cointegration.

At the significance level, the lower and upper critical boundaries are computed. The lower critical bound is used for *I(0)* regressors, and the upper critical bound for *I(1)*. If the F-statistics exceed the upper critical boundaries, a long-term association exists. An F-statistic below the lower critical bound does not reject the null hypothesis of no cointegration. If the F-statistic lies between the upper and lower critical bounds, the inference is inconclusive. The upper and lower critical bounds are used to make inferences as all series have the order of integration *I(0)* and *I(1)*. The error correction model (ECM) is established if long-term relationships exist.

The error correction model (ECM) is specified as follows:

$$\Delta lnC_t = \varphi_0 + \sum_{i=1}^{p} \alpha_{1i}\, \Delta lnC_{t-i} + \sum_{i=1}^{q} \alpha_{2i}\, \Delta lnY_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\, \Delta lnE_{t-i} + \beta_4 dum + \lambda ECT_{i-1} + \mu_t \qquad (10)$$

Where, $\lambda = (1 - \sum_i^p \delta_i)$ speed of adjustment parameter with a negative sign. The Error Correction Term (ECT) $= (1 - \sum_i^p \Delta lnC_{t-i} - \psi X_t)$, is extracted residuals from the long-run equation. $\psi = \frac{\sum_{i=0}^{q} \beta_t}{\alpha}$ is the long-run parameter; and $\alpha_{1i}, \alpha_{2i}, \alpha_{3i}$ are the short-run dynamic coefficients of the model's adjustment long-run equilibrium.

After estimating the ARDL model, the robustness of the model was checked by applying various diagnostic tests. The normality and serial correlation of the error term were checked. Other diagnostics tests performed were autoregressive, white heteroscedasticity, and the functional form of empirical model as in Shahbaz et al. (2013).

Data and Definition of Variables

This study used the time series data covering the period from 1970 to 2018 extracted from the World Development Indicators (WDIs). The justification for adopting this kind of data and the covered period lay in the availability of crucial variables used in this study. Also, it was a period when Tanzania underwent extensive reforming of the industry and environmental sectors. In this period, various industry and environmental policies and institutions were established.

The dependent variable is CO_2 per capita in metric tons. The CO_2 emissions are the major contributors to global warming; hence they are used as a proxy for environmental pollution (Kasten, 2015; Kurt et al., 2016; Shahbaz et al., 2013; Wolde, 2015). The Carbon Dioxide Information Analysis Centre (CDIAC) calculates it annually. It comprises emissions from burning oil, coal, gas, wood, trash, and cement. The GDP per capita and GDP per capita square, measured in Tanzanian shillings, form the explanatory variables. They represent a proxy for early and later stages of economic growth, respectively, as in Wolde (2015).

Using income as the only explanatory variable in this relationship may give biased estimates due to the omitted variable bias. Other variables that often affect environmental quality are added in the relationship. Variables that are added in the relationship include openness measured by technological progress (Wolde, 2015), energy consumption in kilotons of oil equivalent, and the globalization index (Shahbaz et al., 2013). Other variables are service production per GDP, industrial production per GDP (Kurt et al., 2016), population density, and fossil fuel consumption (Kasten, 2015).

Owing to the scope of this study and availability of data, variables that might have affected the relationship between economic growth and environmental pollution were added as control variables. Another added variable in the model, as a control variable, was energy use per capita. Energy use in kg of oil equivalent per capita, as calculated by the International Energy Agency, refers to the use of primary energy before transformation to other end-use fuels. It is equal to indigenous production, plus imports and fuels supplied to ships and aircraft engaged in international transport.

Results and Discussion

Descriptive Statistics

To comprehend the type of data used, descriptive statistics were conducted. This was done in conjunction with dummy variable values. The dummy variable values were Pre-EMA, which refer to the years before 2004 when the Environment Management Act (EMA) was passed; and Post-EMA, which refers to the years following the passage of EMA and the establishment of the National Environment Management Council (NEMC). The results shown in Table 1 indicate that during the years after EMA was adopted, the average absolute values of GDP per capita, CO_2 per capita, and energy per capita were greater compared to the years before. After EMA, the average absolute values of all variables were higher than the overall average. All value ranges were less homogeneous and more widely distributed compared to their log values, which were more evenly distributed and uniform.

Table 1: Descriptive Statistics

Variable	Overall	Pre_EMA	Post_EMA	Min	Max
Y_t	444838	94113	1321650.6	1221.218	2291529
C_t	0.131	0.11	0.182	0.066	0.227
E_t	432.363	421.373	469.728	361.166	542.286
lnY_t	11.056	9.884	13.987	7.108	14.645
lnC_t	-2.093	-2.243	-1.716	-2.713	-1.483
lnE	6.063	6.037	6.151	5.889	6.296
T	**49**	**35**	**14**		

Trend of Economic Growth, Energy Use and CO_2 Emissions in Tanzania

Tanzania's GDP per capita trend indicates a generally upward trend. From the 2000s onward, there was a rapid upward trend (Figure 2). Figure 3 shows Tanzania's trends in CO_2 emissions (measured in metric tons per person), and energy use. From 1970 through the middle of the 1980s, the trajectory of CO_2 emissions fluctuated, although overall it was decreasing. The trajectory of energy use during the same period is similar to the declining trend of CO_2 emissions. Both CO_2 emissions and energy consumption have been seen to increase since the mid-1990s. Figures 2 and 3 can be compared; and it can be seen that the general trends for all three variables are comparable. Since the middle of the 1990s, GDP per capita, CO_2 emissions per capita, and energy use per capita have all increased. For the same time period, an increase in income level can be linked to an increase in CO_2 emissions and energy use. Changes in institutional and legal structures may also play a role, spurring an increase in GDP, energy use, and, ultimately, carbon emissions.

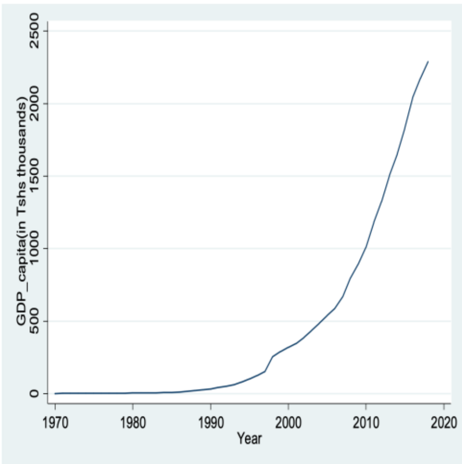

Figure 2: Trends of GDP per Capita

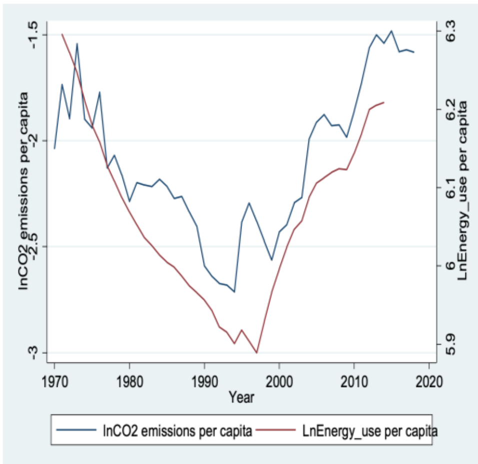

Figure 3: Trends of CO_2 Emissions and Energy Use in Tanzania

Stationarity Analysis

According to the results of the unit root process testing presented in Table 2, there is a unit root problem with the GDP and its square, CO_2 emissions, and energy use at the level; but all series are stationary at the first difference, with intercept and trend. The Z-Andrews test revealed one structural break for each of the series after examining the potential for structural breaks in the data (Table 3). In 1987 and 2004, respectively, there was a fundamental break in GDP and CO_2 emissions. The structural break in the energy use data occurred in 1995.

Table 2: Unit Root Test of Variables at Levels and 1st Difference

	At level		At 1st difference	
	t-Statistic	*Time break*	*t-Statistic*	*Time break*
lnY_t	-2.090	1987	-6.661*	1999
lnY_t^2	-2.090	1987	-6.661*	1999
lnC_t	-2.478	2004	-10.936*	1995
lnE_t	-6.223*	1998		

Note: * significant at 1 percent level

Table 3: Zivot-Andrews Structural Break Trended Unit Root Test

Variables	ADF		PP	
	At level	*At 1st difference*	*At level*	*At 1st difference*
lnY_t	-0.40	-2.83**	-0.65	-4.24***
lnY_t^2	-0.40	-2.83**	-0.65	-4.24***
nC_t	-1.33	-4.268***	-1.28	-9.11***
lnE_t	-1.80	-3.561**	-1.44	-3.55**

Note: * Significance at 10% level, ** at 5% level and *** at 1% level

ARDL Cointegration Test

The ARDL bounds testing procedure requires the determination of appropriate lag order of the variables. Different lag length criteria were applied and the results are presented in Table 4. The model with the lowest information criteria was selected. This decision rule ensures that the error term is mis-specified (Loiboo et al., 2021). Based on Schwarz's Bayesian Information Criterion (SBIC) the selected model was ARDL (2, 2, 1, 2).

Table 4: Optimal Lag for Each Variable

lag	AIC	HQIC	SBIC
2	-2.2813*	-2.2364*	-2.1608*
2	-0.8945*	-0.8500*	-0.7745*
1	-1.2551*	-1.2252*	-1.1749*
2	-5.8557	-5.8108	-5.7352*

Note: *Significant at 1%

The confirmation of whether cointegration exists between economic growth, CO_2 emissions and energy use was done by calculating F-statistic with the help of bound testing. Results reported in Table 5 show that the F-statistic was 8.79 when CO_2 emissions are used as the dependent variable. Since the F-statistic value is greater than the upper bounds at 0.01, 0.05 and 0.10 significance levels, the null hypothesis of no cointegration between variables is rejected. This implies that the variables used in the analysis have a long-run relationship.

One econometric problem of the ARDL bounds testing, developed by Pesaran et al. (2001), is that it does not have information about a structural break that arises in the series. With the structural break in any of the series, the bounds test will yield inconsistent results. In overcoming this problem, the Gregory-Hansen cointegration approach, developed by Gregory and Hansen (1996), was applied. The testing approach was developed for cointegration testing when controlling a single structural break pointed out by the Zivot-Andrews unit root test. Shahbaz (2012) opined that Gregory-Hansen cointegration test approach provides consistent and reliable results compared to other approaches. The null hypothesis of the Gregory-Hansen test is that there is no cointegration at the breakpoint against the alternative that there is cointegration at the breakpoint. The results of the Gregory-Hansen cointegration test are reported in Table 6.

Table 5: Results of ARDL Cointegration Test

Estimated models	$C_t = f(Y_t, Y^2_t, E_t)$	$Y_t = f(C_t, Y^2_t, E_t)$	$Y^2_t = f(C_t, Y_t, E_t)$	$E_t = f(C_t, Y_t, Y^2_t)$
F-Statistics	8.79*	2.731	3.152	3.166
Critical Values	1% level			
Lag order	1,0,0,0,0	2,2,0,0,0	2,0,2,0,0	2,1,0,1,0
Lower bounds	3.74			
Upper bounds	5.06			
R2	0.907	0.992	0.992	0.814
Adj-R2	0.900	0.991	0.990	0.775

Note: *Significant at 1%

Table 6: Gregory-Hansen Structural Break Cointegration Test

Model	$C_t=f(Y_t, Y^2_t,E_t)$	$Y_t=f(C_t, Y^2_t, E_t)$	$Y^2_t=f(C_t, Y_t, E_t)$	$E_t=f(C_t, Y_t, Y^2_t)$
ADF-test	-6.28*	-4.4	-3.99	-4.72
Break Year	2004	1994	1994	1994
Critical value at 5% level	-6.00	-6.00	-6.00	-6.00

Note: *Significant at 5%

The results in Table 6 reveal that the absolute value of ADF-test and critical value are 6.28 and 6.00, respectively, when CO_2 emissions are used as the dependent variable. Since the ADF test is greater than critical value at 0.05 level of significance, then the hypothesis of no cointegration between variables is rejected. This implies that a long-run relationship between variables exists for CO_2 emissions after allowing for structural break in 2004. The findings from the Gregory-Hansen cointegration test suggest that, overall, the long-run results are robust.

Table 7 displays the results of the long-term marginal effects of GDP, square of GDP, and energy use on CO_2 emissions. The square GDP per capita coefficient (0.01086) is also statistically significant at the 10% level, but has a positive sign; as opposed to the GDP per capita coefficient (0.22297), which is statistically significant at the 10% level, but has a negative sign. This suggests that economic growth and CO_2 emissions have a U-shaped relationship. In other words, an increase in GDP per capita initially causes a decrease in environmental pollution, but once it reaches a specific threshold, it causes an increase in environmental pollution. This empirical finding supports the concept of the inverted EKC. CO_2 emissions rise throughout time as a result of energy use. At the 5% level of significance, the energy use coefficient (2.16), which is positive, is statistically significant. This suggests that Tanzania's high energy usage significantly contributes to environmental pollution.

Table 7: Long Run Conclusion

Dependent variable = lnC_t			
Variable	**Coefficient**	**t-statistic**	**prob. Value**
lnY_t	-0.22297*	-0.41	0.0684
lnY_t^2	0.01086*	0.44	0.0664
lnE_t	2.160854**	2.04	0.048
dum	-.1459648	1.15	0.256
CointEq(-1)	-0.6586	-5.11	0.000
Diagnostic Tests Results			
R-Squared	0.9111		
Adjusted R-Squared	0.9006		
Breusch-Pegan-Godfrey Test	0.694		
White Test	28.37		
Ramsey Reset Test	0.14		
Jague Bera Normality Test	1.082		
Durbin Watson Test	1.994		
F-Statistic Value	86.14		

Note: **Significance at 5% level. *Significance at 10%.

The results of the cointegration model's diagnostic tests are shown in the lower section of Table 7. The estimated R-squared and adjusted R-squared values of 0.9111 and 0.9006, respectively, demonstrate the high explanatory power of the dependent variable relative to the independent variables. In addition, the White Heteroscedasticity test, the Breusch-Pegan-Godfrey test for serial correlation, the Dubin Watson test for autocorrelation, and the Jaque Bera Normality test for residual term were performed. Furthermore, the Ramsey Reset test was run to address the model specification issue. According to the estimates, the values of Dubin Watson and Breusch-Pegan-Godfrey are 1.994 and 0.694, respectively; indicating that the model is free of autocorrelation and serial correlation issues. The Jaque Bera's value of 1.082 indicates that the error term is normally distributed, with a zero mean and covariance. According to the white test value of 28.37, there is no conditional heteroscedasticity issue, which means that the homoscedasticity hypothesis is not rejected. The Ramsey Reset test result of 0.14 demonstrates the model's adequate specification.

The long-run causality between variables was determined by calculating error correction coefficient. It would show the speed of adjustment from short-run imbalances toward long-run equilibrium path. The calculated coefficient should be statistically significant having a negative sign. Based on the results in Table 7, the calculated coefficient is (-0.658585) and it is statistically significant at all levels of significance. This implies that the estimated model will reach long-term balance quickly.

The stability of ARDL bounds testing approach estimates was determined by plotting the CUSUM and CUSUM square tests. The plots of CUSUM (Figure 4) and CUSUM Square (Figure 5) are well within the 0.05 significance level. This implies that the long-term estimated model is stable.

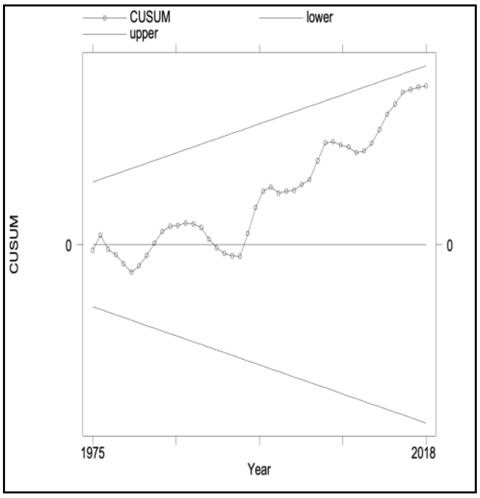

Figure 4: Plot of Cumulative Sum of Recursive Residuals

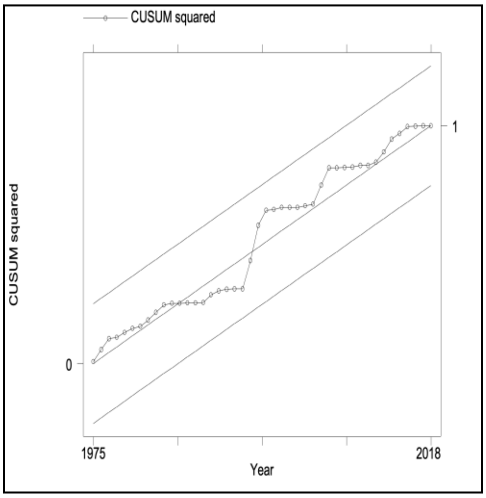

Figure 5: Plot of Cumulative Sum of Squares of Recursive Residuals

Causality Analysis

The study employed the Granger causality approach based on the modified Wald test to analyse the causality between variables. One-way causality is revealed between economic growth and CO_2 emissions (Table 8). The implication is that Tanzania is expanding its economic growth at the expenses of the environment. Also, a bidirectional causality between economic growth and energy use was reported. This suggests that energy is a vital factor among factors of production. Sustainability of economic growth in the long-run will require policies that encourage energy exploration. Moreover, results reveal that energy use Granger causes CO_2 emissions. The implication is that Tanzania should adopt and invest in energy-efficient technologies that have less emissions to the environment.

Table 8: Granger Causality Analysis

Dependent Variables				
lnC_t	**Variable**	**Ch-sq**	**df**	**P-value**
	lnY_t	0.788	2	0.674
	lnY_t^2	0.953	2	0.621
	lnE_t	9.285	2	0.010
lnY_t				
	lnC_t	6.790	2	0.034
	lnY^2	1.216	2	0.544
	lnE_t	12.399	2	0.002
lnY_t^2				
	lnC_t	6.671	2	0.036
	lnY_t	1.186	2	0.553
	lnE_t	12.865	2	0.002
lnE_t				
	lnC_t	3.729	2	0.155
	lnY_t	6.689	2	0.035
	lnY_t^2	7.008	2	0.030

Conclusion and Recommendations

This study sought to explore the link between economic growth and environmental pollution in Tanzania by the approach of the EKC hypothesis using yearly data from 1970 to 2018. Carbon dioxide emissions (CO_2) and GDP were used as the proxies of environmental pollution and economic growth, respectively. Energy use (energy intensity) was incorporated as the potential determinant of environmental pollution and economic growth in Tanzania. The ARDL bounds testing for cointegration approach was applied to test the robustness of long-run relationship between the variables in the presence of structural breaks. Empirical results confirm that the EKC does not exist in Tanzania. Rather, a U-shaped relationship between environmental pollution and economic growth exists. This means that beyond a threshold level of GDP per capita, an increase in GDP per capita is likely to increase CO_2 emissions in Tanzania. Additionally, the study found that there was a causal relationship between energy use and environmental pollution, suggesting that Tanzania is using energy which is not environmentally friendly. Although the absolute value of CO_2 emissions is lower in Tanzania compared to average global emissions, it is increasing faster than the increase in GDP growth. The results of this study concur with those of Villanthenkodath (2021) in India, and Olusegun (2009) in Nigeria. The U-shape relationship between economic growth and CO_2 emissions is significant for policy formulation.

The rapid changes in demographic trends in Tanzania are key factors in altering future demand for energy, industrial goods, land, agriculture, and transportation services; all of which have an impact on the country's GHG emissions. Additionally, Tanzania's fast urbanization, industrialization, advancements in the building industry, and strong demand for vehicles are possible contributors to the rising GHG emissions. Thus, the empirical findings from this study can help Tanzania avoid the mistakes made by other developed nations during industrialization. This can be done by choosing production techniques that promote the use of renewable energy sources, maximizing the use of raw materials, and recovering raw materials and energy from waste. Therefore, it is recommended that Tanzania should make an effort to maintain low levels of pollution emissions by following a strict environmental management policy in addition to other macroeconomic goals. Even if a proactive approach to environmental management does not have an immediate positive effect, in the long-run there will be benefits since there will be less pollution to deal with, and the negative effects of such pollution on humanity will be reduced. Also, the government should implement policies that control population growth and ensure sustainable urbanization practices. This can be achieved by having an appropriate environmental, legal and institutional framework.

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