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Review Article

Environmental Kuznets Curve Hypothesis in Ethiopia

Alemayehu Ethiopia Derege*

**Assistant Professor at Adama Science and Technology University, Ethiopia.*

Corresponding Author: Alemayehu Ethiopia Derege, Assistant Professor at Adama Science and Technology University, Ethiopia.

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Abstract

This study used regional panel data from Ethiopia to examine the degree to which Ethiopia adhere to the environmental Kuznets curve hypothesis and, in turn, estimate the extent to which its people are willing to contribute to environmental development. According to the research, the country complies with the environmental Kuznets curve hypothesis; though environmental resources are regarded either basic or inferior commodity. In relatively more urbanized regions (Harari and Addis Ababa), EKC is U-shaped, negating the hypothesis. During the short run, environmental willingness to pay is typically seen to be low across the nation, with residents of states with higher levels of forestation being readier to pay for a cleaner environment. The study concludes that economic development takes precedence over environmental development and suggests pro-growth economic policies backed by environmental development assistances.

Keywords: EKC, Environmental Policy, Economic Growth, Ethiopia.

Introduction

Income is the dominant and most important factor for quality of life and national development. It measures a country's overall performance in socio-economic, political and environmental terms. In the early stages of civilization, everything was supplied by land [land being more abundant than the other important factors of production, labour and capital]. The quality of the environment was very good and people did not spend a dime to be more productive. As the population continues to grow with constant technology and land, the degradation of natural resources requires more invention and simplification. Human civilization was primarily aimed at improving the efficiency of relatively very scarce resources [such as labour] due to the very high levels of natural resources. Invented early in civilization, heavy machinery made people more productive and simplified the use of the vast natural resources available to humans.

Over the course of time, the expansion of heavy machinery and the expansion of industrialization began to pollute the environment by releasing highly hazardous chemicals, gases, etc. from air, liquids and solid non-disposable substances. The dominance of the industrial sector over the agricultural sector [green economy] has paved the way for exploitation of natural resources [1-4]. Early industrial developments were aimed at simplifying the time-consuming and labour-intensive agricultural activities. This leads to a gradual deterioration of the accumulation of natural resources, which in turn increases desertification [least developed countries] and pollution [developed countries]. The parallel growth of income and environmental degradation is viewed as a natural phenomenon and is usually unavoidable during the productive stage of economic development. During this period, people show less interest in environmental protection and society becomes less willing to contribute to environmental protection [5, 6].

The expansion of the industrial sector has brought pollution [environmental degradation]. Dozens of people suffer from toxic substances released into the environment and during the period of consumption and late production, people started to demand more consumption of quality environment to show the improvement of their living standards. End-to-end government is a means by which simple and less polluting technologies can be implemented to improve the welfare of society. It is often used in combination with carbon trading [market approaches] and government tools [taxes and subsidies] to limit environmental degradation.

Many countries, especially developed ones, have started to allocate large amounts of money to climate protection measures, environmental protection measures, and environmentally friendly, clean and green economic policies. Thus, at later stages of industrial development, there is a strong positive correlation between environmental quality and public environmental spending. Early industrial development involved heavy and polluting machinery, and these technologies created many health problems. A major concern observed in the least developed countries is that the income levels in these countries are insufficient to finance the provision of high-quality environmental goods [7]. Least developed countries therefore seem to have to choose between economic development and environmental development, neither of which seems achievable with the current resources of these countries. Researchers are therefore interested in ascertaining whether the environmental Kuznets curve hypothesis is consistent with Ethiopian reality, thereby analysing the extent to which Ethiopian people are willing to contribute to environmental quality.

1.1. Theoretical Overview

The relationship between economic growth and environmental degradation was framed by his EKC theory [8]. According to the Environmental Kuznets curve hypothesis, economic growth first degrades the environment to the minimum economic growth required for environmental validation, whereby marginal economic growth improves environmental growth. There are many justifications for Kuznets' inverted U-shaped environmental curve, and some justifications for this hypothesis include;

- Empirical Evidence of Declining Pollution with Economic Growth: As incomes continue to rise, people turn to cleaner, lighter technologies that are less costly than previously heavily polluting technologies.
- Reserve Income with Growth: After basic needs are met and people want to contribute more to environmental standards, marginal income from high growth will be higher.
- Emphasis on living standards relative to real GDP: people in economic development place more emphasis on improving living standards than simple GDP.
- Improved technology: Inventions are dependent only on the availability of resources, with the potential for resource depletion. Inventors focus on extremely lightweight and renewable resources to invent cleaner new technologies.
- Solar Energy and Renewable Energy: In terms of resource availability, pollution and production costs, the world is now starting to look to the use of solar energy and renewable energy as its primary energy source.
- Industry Shrinkage: Structural changes at the stage of civilization are inevitable. This process progresses from agricultural development to industrial development and is taken over by the service sector at the final stage. The service sector is much less polluted than his first two.
- Government Regulations: Governments usually enact regulations in the form of taxes and subsidies to resolve externalities.
- Diminishing marginal utility of income: An increase in income decreases marginal utility. Individuals whose income has increased significantly want to improve other aspects of their standard of living.

Therefore, before the early agricultural or industrial revolutions, resources were pristine and the environment cleaner. However, as the economy moves to industrialization, resources are depleted and the environment is polluted. On the other hand, during post-industrial economic growth, people start paying for a cleaner environment and developing more efficient and environmentally friendly technologies.

1.2. Empirical review

In addition to knowing the impact of climate change on a country's economic performance, it is equally important to know whether people are willing to pay to protect the environment. Income elasticity of demand [willingness to pay for environmental protection] can be used to measure the degree of people's response to environmental protection. A leading hypothesis is that in the early stages of economic development, people are less willing to contribute to environmental protection because they want to improve the public good rather than the quality of life. Consume a more desirable product [such as a higher quality environment]. This hypothesis clearly shows that pollutants are inversely proportional to income, so it may not be realistic for least developed countries to contribute more to the environment in the early stages of development.

In the following paragraphs, we look at different empirical evidence produced by different researchers regarding the EKC hypothesis. Few attempts have been made to assess the effectiveness of public environmental spending in curbing environmental problems in Ethiopia. National governments are trying to reduce environmental problems by providing public funds to reduce environmental problems [particularly pollution] at the local and federal structural level. Ademet et al. used time series data and a VEC model to examine the relationship between economic growth and environmental degradation in Ethiopia, showing the existence of short-term and long-term relationships. The results suggest that long-term economic growth can help improve environmental quality and/or reduce environmental degradation, while population growth exacerbates environmental degradation [9].

Demissew Beyene & Kotosz tested the EKC hypothesis for 12 East African countries using a pooled mean group (PMG) approach for the period 1990-2013 and found that the bell-shaped EKC hypothesis and economic activities in East African countries do not lead to CO2 emissions [5]. The authors adhere to environmental protection policies, technological advances, and contemporary industrial policies to effectively shape sustainable economic growth in East African countries. Al Murali et al. used data from 170 countries to examine the EKC hypothesis and the role of government in pollution reduction. The author applied the System Generalized Moments Model (GMM) method and classified the countries into three groups [countries with high, medium and low government effectiveness] [7]. The study found that government effectiveness significantly reduces carbon emissions in countries with high and moderate government effectiveness. The paper also proved the EKC hypothesis for countries with high and moderate government effectiveness, and disproved it for countries with low government effectiveness.

According to this study, government commitment to environmental policy is a key factor driving the EKC hypothesis. Setyari & Kusuma sought to detect the presence of EKC using a sample of 62 countries classified into four subsamples based on per capita income from 1992 to 2017 [3]. The authors used panel data, Error Correction Mechanism (ECM), to analyse short- and long-term effects of economic growth on environmental quality (CO_2 emissions). The study concluded that EKC of the four subsamples he used were inconclusive and related to the 'N' pattern. This result confirms that promoting development at higher levels leads to environmental degradation. Hundie & Daksa used ARDL and DOLS methods to analyse income inequality, economic growth, and carbon emissions in Ethiopia.

The researchers proved Ethiopia's adaptability to the Kuznets curve environment hypothesis [10]. Furthermore, the authors concluded that a modest increase in income inequality would worsen the environment. Tadesse Kebede attempts to test the reality of the Ethiopian ecological Kuznets hypothesis. On the one hand, he confirmed that the Ethiopian government increases the budget for environmental protection in absolute terms every year, but the relationship with the national economy is negligible and varies from state to state [11]. Willingness to pay is very low, which implies confirmation of the ecological Kuznets curve hypothesis, but he did not correctly specify the ecological Kuznets model.

Evidence from Andreoni & Levinson shows that pollutants follow an inverted U in relation to national income, as clearly explained by the Kuznets environmental hypothesis [12]. This paper showed that the EKC hypothesis relies on increased revenue in the technological link between consumption of desirable commodities and reduction of pollutants [unwanted by-products]. EKC is largely independent of externalities, growth dynamics and politics, but is influenced by increased revenues from technologies that reduce environmental degradation the most. A study by is also consistent with his EKC hypothesis in both short- and long-term time ranges.

Providing green services requires huge investments in green innovation [13]. The reality of the ecological Kuznets curve also depends on the types of pollutants released into the environment, the sources of the pollutants, and the living standards of the people to whom the pollutants are released. For example, Cole, Rayner, and Bates used a cross-country panel dataset to analyze environmental Kuznets curves. In this study, the reality of the ecological Kuznets curve hypothesis exists only for local air pollutants, whereas for pollutants associated with global (indirect) emissions, environmental degradation does not affect income. was found to increase monotonically with increasing [14].

Thus, in such cases, tipping points occur at very high-income levels with very large standard errors, unless controlled by multilateral policy initiatives taking place globally. Furthermore, the paper also shows that areas with high concentrations of local pollutants in urban areas peak in areas with low per capita income, while traffic pollution peaks in areas with high per capita income. The EKC hypothesis refers to a mismatch between environmental stress and economic growth. In the early stages of economic growth, environmental pressures are greater than economic growth, and vice versa in late-development scenarios. Analysis by confirms acceptance of the environmental Kuznets curve hypothesis from two main perspectives [15-18].

The first is structural change due to economic growth. According to this hypothesis, economic growth will gradually shift the economy from a clean agricultural economy to the growth of polluting industries and finally to a clean services sector. The second reason is related to people's growing demands for a quality environment. A study by clearly demonstrated that population density, sanitation and education levels were observed as key EKC hypotheses, in addition to environmentally harmful pollutants [19]. The shape of the environmental Kuznets curve also depends on the type of pollutants released into the environment. For example, it has been observed that water pollutants have an N-shaped EKC, whereas other air particles (pollutants) have an inverted U-shape.

When the income elasticity of the willingness to pay for the environment is low, environmental pressure is greater than economic growth, and people are reluctant to pay for environmental protection, and vice versa when the elasticity is high. Studies by show that willingness to contribute to environmental protection depends on the level of income willingness to pay for the environment [20-22]. The findings also clearly show that a country/region's income has a positive impact on people's willingness to pay. In countries with high incomes willing to pay for the environment, environmental protection policies are effective because people contribute more positively to a quality environment.

Therefore, in addition to assessing the impact of climate change and its reforms on a country's economic activity, it is important to measure how positively people are contributing to environmental protection. Public environmental policies can effectively contribute to the fight against environmental degradation if people are willing to pay. People's unwillingness to generate income may lead governments to look for second best solutions instead of externally funding environmental degradation. It is even more important to integrate environmental policies into national development policies. Sustainable development programs are very important for improving quality of life.

2. Data and Methodology

This study was designed to test the environmental Kuznets curve hypothesis, based on the relationship between income and national public environmental spending. The EKC hypothesis was derived from the Nobel Prize-winning concept of the inverse U growth inequality curve developed by Kuznets [8]. It states that growth in the early stages of economic development deteriorates the environmental quality, which will gradually improve with the country's continued economic development. This idea was partially explained by the structural change (transformation) of the economy [from heavy industry to light industry, from polluting industry to cleaning industry]. A country's economic growth brings with it an environmentally friendly technological element (green machines), and such structural changes can lead to reductions in environmental spending compared to counterfactual situations in which transformation does not lead to reductions in public environmental spending.

The downwardly inverted portion of the environmental

Kuznets curve can also be explained by the increasing demand for environmental quality as income increases [23]. This study examines the relationship between income (GDP per capita) and public environmental expenditure (PEE per capita). In the EKC test, researchers used the elasticity of public environmental spending to income. Environmental goods are not private goods and cannot be explained by the income elasticity of demand. However, the relevant elasticities concepts that should be used to describe environmental goods are income elasticity of willingness to pay, income elasticity of hypothetical price, price elasticity of income, income elasticity of environmental spending, and environmental improvement income elasticity [20, 23-25]. Environmental elasticity of income is usually expressed as the ratio of traditional income elasticity to price elasticity [25].

Various references discuss the expected size and degree of environmental willingness to pay. According to, the price elasticity of demand for environmental goods is inelastic and the income elasticity of demand is positive and elastic. It is said that people have a strong interest in consuming more of clean environmental goods, regardless of price or income [26]. Willingness declines and the elasticity of willingness to pay for environmental goods becomes smaller in the long run and higher in the short run. Flores & Carson argue that the level of environmental willingness to pay cannot be determined by the consumption of environmental goods [24]. Parallel to this idea, research by has led to the conclusion that environmental goods are ordinary goods rather than luxuries, leading to an increasing demand for quality environment [24, 25].

These researchers argue that poor people spend a larger proportion of their income on consuming environmental goods than rich people. In light of these arguments, this study estimated the ratio of national public environmental expenditures to income, considering Kuznets's environmental hypothesis. To answer how change in income of the Ethiopian people is related to environmental consumption, the researcher used secondary data collected by the Ministry of Finance and Economic Cooperation (MoFEC) from fiscal year 2010/11 to fiscal year 2020/21. Ethiopia Regional Environmental Expenditure Data are all internal public expenditures devoted to greening the environment, pollution control, waste management, and environmental protection are collected and all foreign sources of funding used to finance emissions/environmental degradation is excluded. To estimate the income elasticity of environmental spending, we build a panel data model for Ethiopia (using regional environmental spending as observations and the period 2010/1 to 2020/21).

2.1. Model Specification

Climate change and economic growth are closely related. Changing climatic conditions [environmental degradation] adversely affect the economic performance of certain countries. However, environmental reform programs [mitigation, public environmental spending, loans, grants, aid, etc.] are widely implemented to control and mitigate climate change. Many researchers have attempted to analyze the relationship between public environmental spending and income [11, 17, 18, 27, 28]. However, given the importance of environment to economy, very few and updated new researches have been conducted in Ethiopia to test the compliance of EKC hypothesis. Accordingly, using the environmental Kuznets curve, the researcher estimated the EKC model equation to test viability and causality between environmental development and Economic growth. According to the environmental Kuznets hypothesis, economic development first degrades environmental quality, which gradually improves with economic prosperity [28, 29].

Environmental economics is based on the basic assumption of free market systems in which the demand and supply of environmental goods and services are determined by free market forces. The individual demand for environmental goods is determined by the price of environmental goods (PE), price of substitute goods/price of non-environmental goods (PNE), social income (Y), human well-being/health, etc. This can be represented as

$$\mathbf{D}^i(\mathbf{E}_\alpha) = \Psi(\mathbf{P}_E, \mathbf{P}_{NE}, \mathbf{Y}, \mathbf{H}) \ldots\ldots\ldots\ldots\ldots(eqn.1)$$

Where

$D^i(E_\alpha)$	Individual Demand for green environmental amenities
P_E	Shadow price of green environmental goods
P_{NE}	Price of substitute or non-green goods
Y	Income
H	Health or wellbeing of the person

The horizontal summation of individual demand curve represents market demand level for the environmental amenities.

$$\mathbf{D}^M(\mathbf{E}_\alpha) = \sum_{i=1}^{N} \mathbf{D}^i(\mathbf{E}_\alpha) \ldots\ldots\ldots\ldots\ldots(\mathbf{eqn.2})$$

Where

$D^M(E_\alpha)$	Market demand for greener environmental goods

While, from the supply side, the willingness to provide cleaner environmental goods, is determined by price of green technologies, price of greener goods relative to non-greener substitute, income, government support for green environment, to government readiness to protect environment, supply of available environmental amenities, technology, and the like.

$$\mathbf{S}^i(\mathbf{E}_\alpha) = \Phi(\mathbf{P}_E, \mathbf{P}_{NE}, \mathbf{Y}, \mathbf{G}, \mathbf{T}) \ldots\ldots.(\mathbf{eqn.3})$$

Where

$S^i(E_\alpha)$	Individual supply of greener (environmental amenities)
P_E	Price of green environment
P_{NE}	Price of non-greener (price of substitute goods)
Y	Income
G	Government support for greenery
T	Technology

The market supply for green environments can be written as,

$$S^M(E_\alpha) = \sum_{i=1}^{N} S^i(E_\alpha) \ldots\ldots.(eqn.4)$$

Where;

$S^M(E_\alpha)$	Market supply for environmental amenities
P_E	Total population

Using the equation (2 and 4), we can determine market equilibrium for endogenous variables income and price for green environment, as

$$D^M(E_\alpha) = S^M(E_\alpha) \ldots\ldots..(eqn.5)$$

Following equation (5) we determine equilibrium, for environmental goods. The study used PEE (public environmental expenditure) to proxy the ratio of price of green technology to non-greenery environmental goods. While, income is used to proxy national income/economic growth. Assuming economic growth determines environmental expenditure (subjected to causality test) and it can be written as follows.

$$E_E = \Psi(Y,) \ldots\ldots\ldots(eqn.6)$$

The standard EKC model, based on eqn. (6), including the one used in is expressed, in real terms, as follows [30].

$$\ln\left(\frac{PEE}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2\left(\ln\left(\frac{GDP}{P}\right)\right)^2_{it} + \varepsilon_{it} \ldots.(eqn.7)$$

$$\varepsilon_{it} : \; N\left(0, \delta_\varepsilon^2\right) \qquad \varepsilon_i : \; \left(0, \delta_\varepsilon^2\right)$$

error term is assumed to be identically and independently distributed with mean zero and constant variance.

i. Stands for regional subscript of Ethiopia [Oromia, Amhara, Addis Ababa, Harari, and SNNP] and t stands for time period between 2015/11 to 2020/1.

Where PEE is public environmental expenditure, P is population; GDP (gross domestic product) is income of the country.

If we allow dynamism to equation 7, the static panel data that can be specified with the help of fixed effect, random effect, GLS, can also be estimated with the help of ARDL model. The ARDL model requires (x_{it}) to be purely I (0) or I (1) or co-integrated (see Table 12). The goodness of fit determines the ideal model that should be used for the interpretation (see Table 7, Table 8, Table 9, Table 10). The dynamic pooled mean group form of equation 7 can be generalized with ARDL model as:

$$y_{it} = \sum_{j=1}^{p} \delta_i y_{i,t-j} + \sum_{j=0}^{q} \beta_{ij}^{'} x_{i,t-j} + \varphi_i + e_{it} \ldots(eqn.8)$$

Where is the dependent variable, (x_{it}) is kx1 vector that allowed to be purely I(0) or I(1) or co-integrated; δ_{ij} is coefficient of the lagged dependent variable called scalars; β_{ij} are kx1 coefficient vectors; φ_i is unit specific fixed effects; i=1,..., N; t=1,2,...,T; p, q are optimal lag orders; e_{it} is the error term [31]. The re-parameterized ARDL (p, q, q,...,q) error correction model is specified as:

$$\Delta y_{it} = \theta_i\left[y_{i,t-1} - \lambda_i^{'} x_{i,t}\right] + \sum_{j=1}^{p-1} \xi_{ij} \Delta y_{i,t-j} + \sum_{j=0}^{q-1} \beta_{ij}^{'} \Delta x_{i,t-j} + \varphi_i + e_{it} \ldots(eqn.9)$$

Where

θ_i	-(1-δ_i), group specific speed of adjustment coefficient (expected that $\theta_i < 0$)
$\lambda_i^{'}$	Vector of long run relationship
ECT	$\left[y_{i,t-1} - \lambda_i^{'} x_{i,t}\right]$
ξ_{ij} $\beta_{ij}^{'}$	The short run dynamic coefficients

Ethiopia has 10 regional states and two federal cities. Based on the availability of data and the level of environmental emphasis given by each administration, only five of them are incorporated in to the panel data. The first two parameters in the RHS of the equation 7 shows intercept parameter that varies across regions (i) and years (t). The individual specific parameter assumes the income elasticity is the same in all regions at a given income level though the level of public environmental expenditure per capita may differ over regions at any particular income level. The time specific intercept (parameter) accounts for time varying omitted variables and stochastic shocks that are common to all regions. The turning point-income, where public environmental expenditure is optimized, is given by first order condition of public environmental expenditure with respect to income and it can be written as the following equation:

$$\tau = \exp\left(-\beta_1 / \left(2\beta_2\right)\right) \ldots\ldots.(eqn.10)$$

Equation 10 helps us estimate maximum income willingness to pay for environmental development. Environmental degradation goes deteriorating up to the turning point while it starts to be improved beyond the turning point with increasing income of the country. In many papers, EKC is estimated using quadratic panel data. According to, the theoretical interpretation of coefficients and parameters used in the equation 44 is given as follows [16]:

- If $\beta_1 > 0$, $\beta_2 = 0$; the EKC has linear shape and monotonically increasing: as income increases, environmental pressure is increasing.
- If $\beta_1 < 0$, $\beta_2 = 0$; the EKC will have linear shape and monotonically decreasing: as income increases, environmental pressure is decreasing.
- If $\beta_1 > 0$, $\beta_2 < 0$; the EKC will have inverted U-shape: after reaching the threshold, environmental pressure will decrease with increasing income.
- If $\beta_1 < 0$, $\beta_2 > 0$; the EKC will have U-shape.
- If $\beta_1 < 0$, $\beta_2 < 0$; the EKC will have reverse N-shape: environmental pressure decreases first, then increases and later decreases.
- If $\beta_1 = 0$, $\beta_2 = 0$; the EKC will have horizontal line; indicating income does not affect the environmental pressure.

The purpose of the above equation is to estimate the relationship between national public environmental expenditure and income, thereby testing the environmental Kuznets curve hypothesis. Therefore, in the EKC model above, time-specific exogenous variables are included in the model, as used in to maintain parameter stability [16]. If the number of both time and individual identities used in the analysis is less than 25, an appropriate panel data formula is selected to use from pooled OLS, fixed-effects, or random- effects models and the selected models used in this analysis adhere to this rule of thumb.

A fixed effects model treats and as regression parameters, whereas a random effects model treats them as components of random noise, and the explanatory variables are correlated, a random-effects model cannot be estimated consistently, whereas a fixed-effects model can. Fixed-effects models are better suited than random-effects models for analysing the effects of variables that change over time [32, 33]. A fixed effects model removes time-invariant variables, and a random effects model avoids a single invariant variable from the regression model. Preferably, the Hausman test can be used to select an appropriate model to use for the ECK equation above, and the particular Hausman statistic used in the study can be expressed as increase [34].

$$\mathbf{m = q^{'}\left[var(\beta_{FE}) - var(\beta_{RE})\right]^{-1} q.....(eqn.11)}$$

$$where\ q = \beta_{FE} - \beta_{RE}$$

In order to differentiate workability of EKC hypothesis in different time horizon (short run and Long run) the researcher applied equation 8 and 9 specified above. Before running an EKC model, it is recommended to look for various diagnostic tests [heteroscedasticity, stationarity, normality, stability, etc.] [32, 33, 35]. The problem of Heteroskedasticity is not a serious problem in panel data analysis (see Table 5), even if the problem persists, it can be easily resolved by transforming the data to natural logarithms or simply using robust standard errors [36]. Another common diagnostic check performed on the panel dataset is a normality test performed using the Jarque-Bera test [37]. If the null hypothesis is rejected and the alternative hypothesis is supported, the error term is not normal and vice versa (see Table 6).

High-order serial correlation in panel data can be tested with the Breusch-Godfrey test (Breusch & Godfrey). If the null hypothesis is accepted, there is no serial correlation problem and vice versa (see Table 13). If you have serial correlation problems, it's usually a good idea to add the lag of the dependent variable as an explanatory variable. Unit root problems are usually not a serious problem in panel data (counts < 25 for both t and i), but the Leuin-lin-Chu test or the Hadri LM stationarity test can be used to confirm the results [38]. These test statistics used to test the panel's null hypothesis include unit root and, if the p-value is less than 0.05, reject the null hypothesis and test an alternative hypothesis. You can avoid the root-of-one's problem by transforming the original data set using a finite difference method. Given the variables are mixed integrated of order I(0) and I(1), the researcher adopted ARDL model in differentiating short run impacts, of economic growth on environmental development, from the long run (see Table 12, Table 14).

Due to the short form of the panel data model, there is marginal difference between dynamic and static models. In the short panel, the static panel data model has more consistent estimates than the corresponding dynamic panel data model [33]. This is because dynamic panel data lead to structural damage, overestimation, and structural instability. This study performed a causality test using the approach used by Lopez & Weber and found that GDP causes environmental spending, but not the other way around. The endogeniety test, which is less problematic in a multiple regression of small variables, is performed using the method used by [39, 40]. Finally, the above equations (equation 7, 8, 9, and 10) are estimated and interpreted after all panel diagnostic issues have been corrected (see appendix).

2.2. Data Analysis

The main objective of this chapter is to measure the relationship between public environmental expenditures (representing environmental development) and GDP (representing economic growth), thereby testing the environmental Kuznets curve hypothesis based on Ethiopia's regional environmental budget allocation levels. The dataset is a panel organized from selected regions of Ethiopia between 2010/11 and 2020/21. All public environmental budgets allocated for control of environmental degradation (pollutant emissions), mitigation, waste management, and green space are summed to represent total public environmental expenditure. The environmental Kuznets curve assumes that economic growth mitigates environmental deterioration after initial deterioration.

This situation is relevant to the development priorities of certain countries. In the early stages of development, a great emphasis is placed on the country's economic development, and over time, the country's focus shifts to clean environmental consumption. Increasing demands on the environment are related to the modernity and know-how of people living with highly polluting technology. As the marginal utility of heavy equipment declines, the forces of competition and improvement drive people to the best options. However, in the later stages of development, people are interested in using very light and clean technology (environmentally friendly machines) instead of the old and heavy technology used earlier when income was low. This paper analyses the environmental impact of growth and examines whether Ethiopia's development has the prospect of mitigating the environmental degradation assumed in the Kuznets hypothesis.

To achieve this, the researchers employed an environmental Kuznets curve model using both dynamic and static panel model framework. This dataset contains Ethiopian states as crosscutting identities over the last decade. If the environmental Kuznets curve is accepted, it will have a significant impact on public budget allocations and environmental tax accrual rates. Taxes to improve environmental quality are determined by the level of income willingness to pay for environmental goods essential to pollution control. Focusing primarily on the environmental demand side, this paper answers how a country's public environmental spending and revenues (as determined by gross domestic product/ per capita income) are related to each other. Pre-diagnostic (see Appendix A) and post-inference tests (see Appendix B) are implemented before running the environmental Kuznets curve model used in the publication.

2.3. Testing the Environmental Kuznets Curve Hypothesis

The EKC model shown below can be used to test the environmental Kuznets curve hypothesis. This hypothesis assumes that as a country's income increases, the amount of pollution emitted into the environment will gradually decrease. In the early stages of a country's development, growth exacerbates the problem of environmental degradation, but over time, it improves. The relationship between growth and environmental cleaning is primarily related to the increasing demand for a clean environment. According to this hypothesis, as their income increases, these people will have to consume cleaner environmental goods and services. From a demand perspective, higher income indicates a higher ability (or willingness) to pay for new supply.

To meet this demand, many entrepreneurs are looking to create new technologies (usually simple, clean, and green) to replace old, polluting, heavy industry. This type of structural change towards eco-friendly inventions (observed mainly by industrial upgrade/modernization) reduces the amount of harmful chemicals (pollutants) emitted into the environment. On the other hand, the inverse relationship between growth and a cleaner environment is associated with reduced costs of environmental degradation (pollution). Development is usually seen as the best solution to all socio-economic, political and environmental problems. Economically emerging regions tend to use renewable resources to produce very simple, clean and environmentally friendly outputs (services).

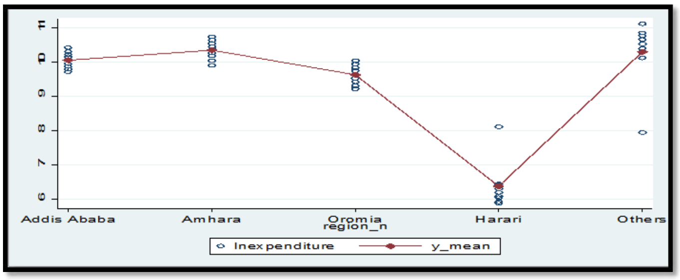
The existence of economies of scale in very large industries drives down the average cost of producing clean and environmentally friendly technologies. Thus, the abatement cost hypothesis states that the total cost of controlling environmental degradation will increase during the early growth stages and will reach a certain tipping point (optimal value) as county revenues continue to increase over time. In either case (increasing demand or decreasing costs), economic development first exacerbates the problem of environmental degradation until incomes reach a tipping point, beyond which incomes increase. In all models shown in Table 1, economic growth is determining (significantly) environmental development.

Table 1: The relationship between Public environmental expenditure and national income of the country.

MODELS VARIABLES	(PMG) ECT	(PMG) SR	(FE) LNPEE	(RE) LNPEE	(GLS) LNPEE
ECT		-0.448			
		(0.449			
D.LNGDP		-2.706			
		(2.693)			
D.LNGDPSQR		0.248			
		(0.219)			
year	0.0310	0.229	0.0866*	-0.0471	-0.0471
	(0.128)	(0.225)	(0.0500)	(0.0482)	(0.0482)
LNGDP	5.412***		0.341*	0.780***	0.780***
	(1.018)		(0.171)	(0.184)	(0.184)
Constant		-488.6	-165.4	101.4	101.4
		(481.7)	(100.1)	(96.68)	(96.68)
EY	4.876	-2.458	0.306	0.74	0.74
Observations	95	95	100	100	100
Number of regions			5	5	5
Number of Groups	5	5			
R-squared			0.285		

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: Stata result, 2023



Source: study result (2023)

Figure 1: Heterogeneity of data of data over cross-section observation

The result of PMG reveals economic growth (both GDP and GDP square) has significant long run effect on environmental cleanness. In the short run, however, any change in economic growth does not influence (statistically insignificant) environmental growth (cleanness). The coefficient of ECT is negative implying the possibility of convergence between variables. The coefficient of ECT represents the fact that the short run disequilibrium can be corrected at the speed of 44.8 percent per annum. The insignificance of ECT represents the absence of causality between economic growth and environmental cleanness in the short run, which would imply that, in the short run, economic growth does not cause (bring) environmental cleanness (development). The results of all the models are almost the same with minor difference. Based on Hausman test (Table 9), Fixed effect model (Fe) is selected to see the static relationship between economic growth and environmental development. Accordingly, the mathematical representation of the environmental Kuznets model used in this research can be written as:

$$\ln\left(\frac{PEE}{P}\right)_{it} = \alpha_i + \gamma_t + \beta_1 \ln\left(\frac{GDP}{P}\right)_{it} + \beta_2\left(\ln\left(\frac{GDP}{P}\right)\right)_{it}^2 + \varepsilon_{it}$$

$$\ln\left(\frac{PEE}{P}\right)_{it} = -165.408 + 0.087(t) + 0.341\ln\left(\frac{GDP}{P}\right)_{it} - 0.035\left(\ln\left(\frac{GDP}{P}\right)\right)_{it}^2 + \varepsilon_{it}$$

$$[0.1068] \quad [0.0915]^* \quad [0.0541]^* \quad [0.0536]^*$$

Where, the values in brackets are p-values for associated variables and asterix show its significance at 10% significance level.

The advocators of EKC hypotheses believe that country need to reach a particular average income level before they can afford to allocate the resources needed to protect the environment. In such case, poor countries do not care much about environment as they have more pressing economic problems to prioritize. The hypothesis postulates that if $\beta_1 > 0$ and $\beta_2 < 0$, the EKC will have inverted U-shape which would mean that during the early phase of development, environment will be degraded but if income continues to increase over time, environmental degradations will be improved. Both signs of both β1 and β2 maintain the original environmental Kuznets curve hypothesis and as a result, the environmental Kuznets curve hypothesis is true for Ethiopia.

Table 2: Environmental Kuznets curve hypothesis and its decision.

Coefficients	Null hypothesis	Environmental Kuznets curve hypothesis	p-values	Decision
β_1	$\beta_1 = 0$	$\beta_1 > 0$	0.0541*	Reject Ho
β_2	$\beta_2 = 0$	$\beta_2 < 0$	0.0536*	Reject Ho

Source: own result, 2023

Except the constant term, all variables have a significant impact on the country's per capita public environmental expenditure. In this study, the environmental Kuznets model is specified in log-log form, so the coefficients automatically handle the elastic interpretation. Based on the above results (Table 1), the income elasticity of willingness to pay for environmental spending is estimated to be 0.74. This means that if the Ethiopia's economic growth increases by 1%, the willingness to pay for quality environment is improved by 0.74%. Furthermore, environmental goods and services are discovered to be inferior goods in the short run (EY = -2.707) and luxury goods in the long run (EY = 4.876). This implies that Ethiopia's economic expansion will almost certainly diminish demand for environmental goods in the short run. However, sustainable economic growth can help to accelerate environmental progress, as the need for clean environments grows.

On average, Ethiopia has an inelastic demand for environmental quality, with the environment considered as either a basic good/service or even an inferior good, in the short run. This can be used to say that at this level, Ethiopia cannot afford to allocate large domestic resources just to protect the environment from destruction. These inelastic demands for environmental quality make it difficult to sustain environmental protection on our own. In other words, this could also mean that environmental quality prevention programs must be complemented by external support. The time coefficient (trend) of the Kuznets environment curve above is statistically significant, indicating that public environmental spending tends to increase over time, regardless of country income growth. A one-year increase in the time trend would increase the country's public environmental spending by 0.087% per year. This means that the future will be better for society if quality environmental products/services are provided.

2.4. Regional Willingness to Pay for Environmental Income in Ethiopia

The willingness to pay for each region used in this panel data model can be analyzed by applying the panel subsample regression technique. This helps us see how a country's regional income relates to environmental protection. Based on that (income potential, level of infrastructure, social superstructure, level of awareness, level of industrialization, etc.), each region may differ in its ability and willingness to pay for public goods (environmental quality). The need for a high-quality environment also depends on the degree of urbanization of individual states and federal cities. The results of this study show that the Kuznets curve holds for Ethiopia (that is, the signs of the coefficients of GDP and GDP squared are positive and negative, respectively).

This means that economic growth initially contributes to environmental degradation, but appears to reduce pollution over time. Addis Ababa and Harari have a high level of urbanisation compared to other regions (Oromia, Amhara, and SNNP). According to this classification, the EKC hypothesis does not hold true in the Harari and Addis Ababa regions (EKC is U-shaped), suggesting that economic growth will initially improve environmental cleanness but over a long period of time, economic growth will actually worsen the environmental cleanness. These are mostly because both public and private investments have been made heavily in highly urbanised areas, and if these trends continue, both FDI and DDI will worsen the state of the environment. On the other hand, the EKC hypothesis is true in other parts of Ethiopia (Amhara, Oromia, and SNNP).

The Ethiopian regions with the greatest levels of environmental willingness to pay are SNNP and Oromia, respectively. Each of these regions has a sizable concentration of forestry, ranking first and second in the nation. These indicate that residents of these areas are more eager to protect the environment from harm and are willing to contribute to its future improvement. The environment is classified as a basic good in all other regions, with the exception of the SNNP region where it is a luxury commodity. In SNNP region, increased income is strongly associated with environmental development (participatory environmental protection). In reality also, peoples' livelihood is strongly associated with by-products of forest protection (e.g. coffee, honey, roots, spices, fruits & vegetables, and other edible forest outputs). Regional economic growth in the regions like (Amhara, Oromia, Addis Ababa, and Harari) has little to no effect on its regional environmental developments. This is due to the low-income elasticity of residents in these four locations.

Table 3: Panel sub-sample regression (regressions for each region within sample time period).

VARIABLES	(Amhara) LNPEE	(Oromia) LNPEE	(Addis Ababa) LNPEE	(Harari) LNPEE	(SNNP) LNPEE
LNGDP	0.0338	0.165	-0.0271	-0.211	5.451
	(0.0204)	(0.124)	(0.0199)	(0.115)	(12.28)
LNGDPSQR	-0.00301	-0.0189	0.00377	0.172*	-0.416
	(0.00197)	(0.0147)	(0.00220)	(0.0688)	(0.854)
year	0.0874***	0.107***	0.100***	0.0247	0.156*
	(0.00330)	(0.0118)	(0.00122)	(0.0640)	(0.0690)
Constant	-165.8***	-205.7***	-192.4***	-43.58	-321.5**
	(6.638)	(23.77)	(2.438)	(128.6)	(124.8)
Mean WTP E_y	277.92534	78.910762	36.517781	1.8510863	697.60912
	0.0278	0.1272	0.0483	0.133	4.619
Mean GDP per capita	21.3	7.73	51.58	21.7	67.9
Observations	20	20	20	20	20
R-squared	0.997	0.995	1.000	0.841	0.092

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Source: study result, 2023

Harari region is the smallest region with no rural areas. The level of per capital income allocated for the environmental protection was very little and as a result, further economic growth in the long run could result in severe environmental deterioration (the coefficient GDP square is positive and significant). The lack of land for forestry development coupled with Harari's industrial development could exacerbates environmental problems. In order to know whether economic growth leads to environmental development or vice versa, it is also crucial to look at the direction of causality between income and environmental expenditure.

2.5. The causality effect of environmental public expenditure

To identify whether environmental public expenditure causes GDP or GDP causes environmental public expenditure, it is crucial to test for causality. The following table shows public environmental expenditure is not significantly affecting income of the country (there is no problem of endogeniety in the model). The p-value of D. LNPEE is greater than 10%, which would mean that environmental public expenditure cannot determine GDP in the short run. However, in the long run, public environmental expenditure can cause significant GDP growth for the country. Therefore, income determines the allocation of public expenditure (see Table 1) and environmental development does not cause economic growth in the short run (see Table 4).

Table 4: Does environmental public expenditure causes GDP?

VARIABLES	(Ethiopia) ECT	(Ethiopia) SR	(Region) Amhara	(Region) Oromia	(Region) Addis Ababa	(Region) Harari	(Region) SNNP
ECT		-0.786***	-0.232	-1.570***	-0.900***	-1.200***	-0.0290
		(0.290)	(0.295)	(0.163)	(0.199)	(0.389)	(0.0971)
D.LNPEE		-1.007	-12.29	-10.55***	19.68	-1.813**	-0.0595
		(5.693)	(18.00)	(3.870)	(14.77)	(0.896)	(0.160)
LNPEE	2.485***						
	(0.209)						
Constant		14.07**	-3.262	-31.30***	-18.64***	-16.83***	-0.318
		(5.618)	(6.661)	(4.382)	(5.170)	(5.851)	(1.777)
Observations	95	95	95	95	95	95	95

Standard errors in parentheses
*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Source: Stata result, 2023

The coefficient of ECT for Ethiopia is negative and significant, representing long run causality between environmental development and economic growth and accordingly, increased environmental protection will lead to economic growth. The coefficient of ECT (Ethiopia) also represents that short run disequilibrium can be adjusted at the speed of 78.6 percent per annum. In the short run, the environmental expenditure does not cause Ethiopia's economic growth, as it does in the long run. In the regions like Oromia and Harari, however, expansionary environmental protection can lead to economic growth even in the short run (see also Figure 3).

3. Conclusion and Policy Implications

The Ethiopia's income elasticity of willingness to pay for environmental goods is less than one, which means that people in Ethiopia regard environmental goods as basic/necessary and are willing to consume less of them (specific minimum amount) as their income levels continued to increase overtime. Sustainable economic growth and development are therefore highly effective in alleviating the problem of environmental destruction, and until the general public reveals the elastic income elasticity of their willingness to pay for the environment, government must continue to increase budget allocations to environmental policy. Improving the income elasticity of willingness to pay for quality environment would allow market power to determine the allocation of environmental budgets through supply and demand.

The results in this paper therefore demonstrate that the environmental Kuznets curve hypothesis works for Ethiopia and its regional states. Economic growth in highly urbanized areas (Addis Ababa and Harari regions) can further deteriorate environmental development. Economic growth can make the environment cleaner if a country can sustain its economic growth over a longer period of time. However, the inelastic willingness to pay for the environment makes it very difficult to implement environmental policies in the short run without external support. A country's domestic resources are insufficient to prioritize the environment over economic concerns, and society's contributions are insufficient to solve environmental degradation. Besides, environmental resources are regarded either basic or inferior goods. In relatively more urbanized areas, more smart green technologies need to be adopted. It is therefore more realistic, at least in the short term, to focus on sustaining economic growth and development policies at the expense of the environment [41].

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References

1. Ahmad, M., Muslija, A., & Satrovic, E. (2021). Does economic prosperity lead to environmental sustainability in developing economies? Environmental Kuznets curve theory. Environmental Science and Pollution Research, 28(18), 22588-22601.

2. Mahmood, H., Maalel, N., & Hassan, M. S. (2021). Probing the energy-environmental Kuznets curve hypothesis in oil and natural gas consumption models considering urbanization and financial development in Middle East countries. Energies, 14(11), 3178.
3. Setyari, N. P. W. (2021). Economics and environmental development: Testing the environmental Kuznets Curve hypothesis. International Journal of Energy Economics and Policy.
4. Tenaw, D. (2021). Getting into the details: structural effects of economic growth on environmental pollution in Ethiopia. Heliyon, 7(7).
5. Demissew Beyene, S., & Kotosz, B. (2020). Testing the environmental Kuznets curve hypothesis: an empirical study for East African countries. International Journal of Environmental Studies, 77(4), 636-654.
6. Hundie, S. K. (2021). Income inequality, economic growth and carbon dioxide emissions nexus: empirical evidence from Ethiopia. Environmental Science and Pollution Research, 28(32), 43579-43598.
7. Al-Mulali, U., Gholipour, H. F., & Solarin, S. A. (2022). Investigating the environmental Kuznets curve (EKC) hypothesis: does government effectiveness matter? Evidence from 170 countries. Environment, Development and Sustainability, 1-16.
8. Kuznets, S. (2019). Economic growth and income inequality. In The gap between rich and poor (pp. 25-37). Routledge.
9. Adem, M., Solomon, N., Movahhed Moghaddam, S., Ozunu, A., & Azadi, H. (2020). The nexus of economic growth and environmental degradation in Ethiopia: time series analysis. Climate and development, 12(10), 943-954.
10. Hundie, S. K., & Daksa, M. D. (2019). Does energy-environmental Kuznets curve hold for Ethiopia? The relationship between energy intensity and economic growth. Journal of Economic Structures, 8(1), 1-21.
11. Tadesse Kebede. (2015). Trends and Practices of Public Environmental Expenditure in Ethiopia [Masters, Addis Ababa University]. http://webcache.googleusercontent.com/search?q=cache:IZs6IQVAaBAJ:etd.aau.edu.et/handle/123456789/11408%3Fshow%3Dfull+&cd=9&hl=en&ct=clnk&gl=in
12. Andreoni, J., & Levinson, A. (2001). The simple analytics of the environmental Kuznets curve. Journal of public economics, 80(2), 269-286.
13. Shahbaz, M., Dube, S., Ozturk, I., & Jalil, A. (2015). Testing the environmental Kuznets curve hypothesis in Portugal. International Journal of Energy Economics and Policy, 5(2), 475-481.
14. Cole, M. A., Rayner, A. J., & Bates, J. M. (1997). The environmental Kuznets curve: an empirical analysis. Environment and development economics, 2(4), 401-416.
15. Dinda, S. (2004). Environmental Kuznets curve hypothesis: a survey. Ecological economics, 49(4), 431-455.
16. Ogundipe, A., Alege, P. O., & Ogundipe, O. (2014). Income heterogeneity and environmental Kuznets curve in Africa. Journal of Sustainable Development, 7(4).
17. Stern, D. I., Common, M. S., & Barbier, E. B. (1996). Economic growth and environmental degradation: the environmental Kuznets curve and sustainable development. World development, 24(7), 1151-1160.
18. Suri, V., & Chapman, D. (1998). Economic growth, trade and energy: Implications for the environmental Kuznets curve. Ecological Economics, 25(2), 195–208.
19. Orubu, C. O., Omotor, D. G., Awopegba, P. O., & Ababa, A. (2009, March). Economic growth and environmental quality: Searching for Environmental Kuznets Curves in Africa. In CSAE conference, University of Oxford, UK.
20. Hanemann, W. M. (1991). Willingness to pay and willingness to accept: how much can they differ? The American Economic Review, 81(3), 635-647.
21. Hökby, S., & Söderqvist, T. (2003). Elasticities of demand and willingness to pay for environmental services in Sweden. Environmental and resource economics, 26, 361-383.
22. Horowitz, J. K., & McConnell, K. E. (2003). Willingness to accept, willingness to pay and the income effect. Journal of economic behavior & organization, 51(4), 537-545.
23. Bergstrom, J. C., Stoll, J. R., & Randall, A. (1990). The impact of information on environmental commodity valuation decisions. American Journal of Agricultural Economics, 72(3), 614-621.
24. Flores, N. E., & Carson, R. T. (1997). The relationship between the income elasticities of demand and willingness to pay. Journal of environmental Economics and management, 33(3), 287-295.
25. Kristrom, B., & Riera, P. (1996). Is the income elasticity of environmental improvements less than one?. Environmental and resource Economics, 7, 45-55.
26. Garrod, G., & Willis, K. G. (1999). Economic valuation of the environment. Books.
27. Dinda, S. (2004). Environmental Kuznets curve hypothesis: a survey. Ecological economics, 49(4), 431-455.
28. Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. World development, 32(8), 1419-1439.
29. Magnani, E. (2000). The Environmental Kuznets Curve, environmental protection policy and income distribution. Ecological economics, 32(3), 431-443.
30. Grossman, H. I. (1991). A general equilibrium model of insurrections. The American Economic Review, 912-921.
31. Im, K. S., Pesaran, M. H., & Shin, Y. (2003). Testing for unit roots in heterogeneous panels. Journal of econometrics, 115(1), 53-74.
32. Gujarati, D. N., & Porter, D. C. (2003). Panel Data Regression Models. Basic Econometrics, 4.
33. Wooldridge, J. M. (2010). Econometric analysis of cross section and panel data. MIT press.
34. Hausman, J. A. (1978). Specification tests in econometrics. Econometrica: Journal of the econometric society, 1251-1271.
35. Maddala, G. S., & Lahiri, K. (1992). Introduction to econometrics (Vol. 2, p. 525). New York: Macmillan.
36. Baltagi, B. H., & Baltagi, B. H. (2008). Econometric analysis of panel data (Vol. 4). Chichester: Wiley.
37. Jarque, C. M., & Bera, A. K. (1987). A test for normality of observations and regression residuals. International Statistical Review/Revue Internationale de Statistique, 163-172.
38. Hadri, K. (2000). Testing for stationarity in heterogeneous panel data. The Econometrics Journal, 3(2), 148-161.

39. Lopez, L., & Weber, S. (2017). Testing for Granger causality in panel data. The Stata Journal, 17(4), 972-984.
40. Çağlayan Akay, E., & Kangallı Uyar, S. G. (2021). Endogeneity and nonlinearity in the environmental Kuznets curve: a control function approach. Panoeconomicus.
41. Breusch, T. S., & Godfrey, L. G. (1981). A review of recent work on testing for autocorrelation in dynamic simultaneous models. Macroeconomic analysis, essays in macroeconomics and economics, 1, 63-100.

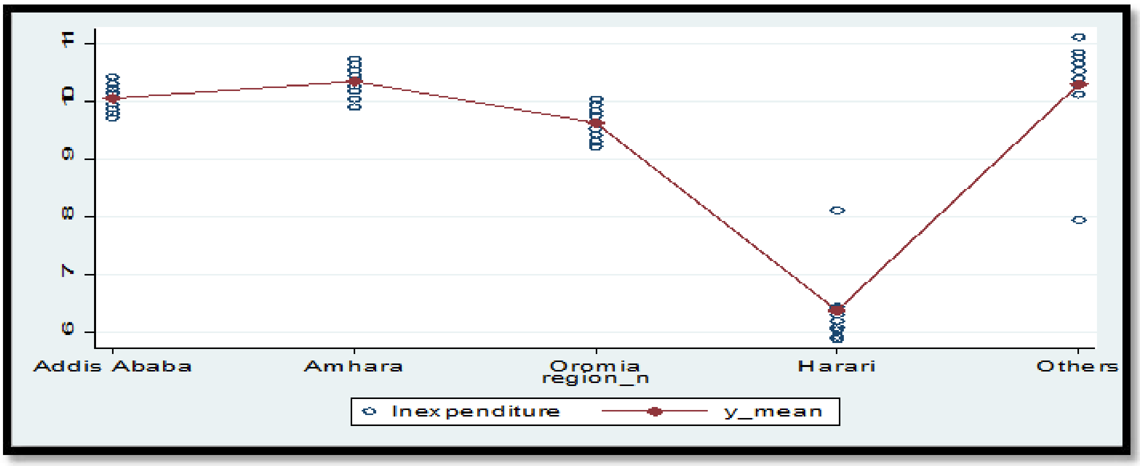
Appendix: Pre-diagnostic testing

A1. Heteroskedasticity test

```
. xttest3

Modified Wald test for groupwise heteroskedasticity
in fixed effect regression model

H0: sigma(i)^2 = sigma^2 for all i

chi2 (5)  =     60437.37
Prob>chi2 =       0.0000
```

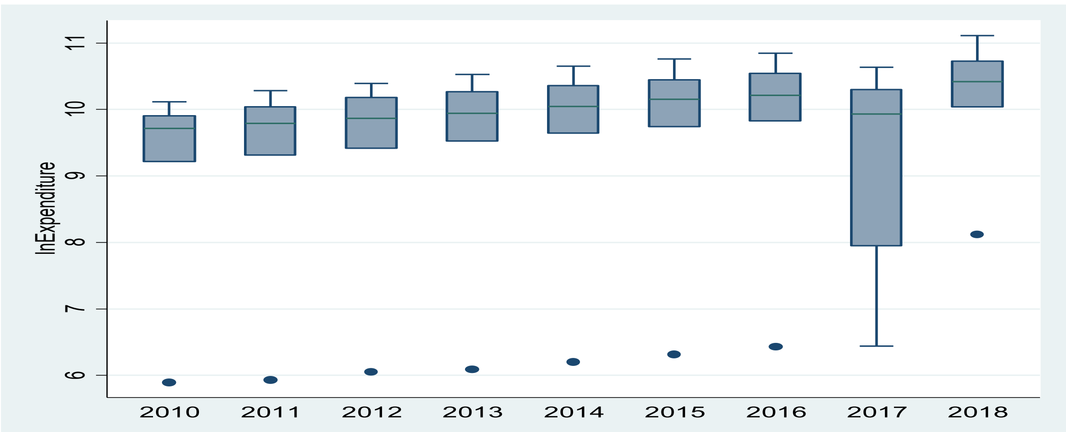
Table 5: Heteroskedasticity test

A2. Heterogeneity test



Source: study result (2023)

Figure 1: Heterogeneity of data of data over cross-section observation



Source: own analysis (2023)

Figure 2: Heterogeneity of data of data over time

A3. Normality test

Table 6: Skewness/Kurtosis tests for Normality

Variable / statistic	Pr(Skewness)	Pr(Kurtosis)	adj	Prob>chi2
lnexpenditure	0.8302	0.5975	0.32	0.8502
lngdp	0.9530	0.4188	0.68	0.7103
lngdpsqr	0.1950	0.5849	2.12	0.3461

Source: study result (2023)

Table 7: Correlation coefficicient between economic growth and environmental growth

PWCORR LNPEE LNGDP LNGDPSQR, star(5)			
	LNPEE	LNGDP	LNGDPSQR
LNPEE	1.0000	0.8226*	0.6945*
LNGDP	0.8226*	1.0000	0.9542*
LNGDPSQR	0.6945*	0.9542*	1.0000

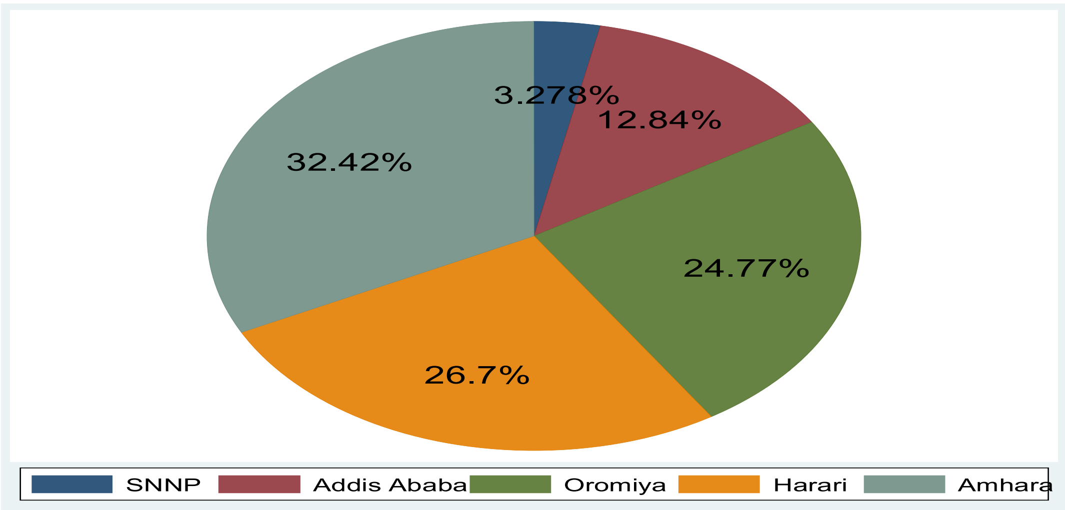


Figure 3: Public environmental expenditure per GDP by regions

B.Post-diagnostics

B1: Breusch and Pagan Lagrangian multiplier test for random effects

Table 8: Breusch and Pagan Lagrangian multiplier test for random effects

```
. xttest0

Breusch and Pagan Lagrangian multiplier test for random effects

        lnExpenditure[region_n,t] = Xb + u[region_n] + e[region_n,t]

        Estimated results:
                         |       Var     sd = sqrt(Var)
                ---------+-----------------------------
               lnExpen~e |   2.576669       1.6052
                       e |   .2381118       .487967
                       u |   .1329966       .3646869

        Test:   Var(u) = 0
                             chibar2(01) =     5.95
                          Prob > chibar2 =   0.0074
```

Source: Stata result, 2023

B2. Hausman Test

Table 9: Hausman test result

Correlated Random Effects - Hausman Test
Equation: Untitled
Test cross-section random effects

Test Summary	Chi-Sq. Statistic	Chi-Sq. d.f.	Prob.
Cross-section random	25.311844	3	0.0000

Cross-section random effects test comparisons:

Variable	Fixed	Random	Var(Diff.)	Prob.
LNGDP	0.340829	0.780161	0.007691	0.0000
LNGDPSQR	-0.035025	-0.039854	0.000041	0.4510
YEAR	0.086568	-0.047118	0.001016	0.0000

Source: Eviews result, 2023

B3. Wald Test for Goodness of fit

Table 10: The Wald statistics

Wald Test:
Equation: Untitled

Test Statistic	Value	df	Probability
F-statistic	15.87366	(4, 37)	0.0000
Chi-square	63.49466	4	0.0000

Null Hypothesis: C(4)=C(5)=C(6)=C(7)=0
Null Hypothesis Summary:

Normalized Restriction (= 0)	Value	Std. Err.
C(4)	-0.164563	0.396661
C(5)	-0.871656	0.387551
C(6)	-0.396784	0.380722
C(7)	-3.681081	0.733745

Restrictions are linear in coefficients.

Source: Eviews result, 2023

B4. Testparm (goodness of fit)

Table 11: Testing significance of the inclusion of time dummies in fixed effect model

testparm i.year	Test result
(1) 2008.year	0
(2) 2009.year	0
(3) 2010.year	0
(4) 2011.year	0
(5) 2012.year	0
(6) 2013.year	0
(7) 2014.year	0
(8) 2015.year	0
F(8, 30)	1.75
Prob > F	**0.1265**

Source: Stata result, 2023

B5. Cross-sectional independence test

Table 12: Residual cross-section dependence test

Residual Cross-Section Dependence Test
Null hypothesis: No cross-section dependence (correlation) in residuals
Equation: Untitled
Periods included: 9
Cross-sections included: 5
Total panel observations: 45
Cross-section effects were removed during estimation

Test	Statistic	d.f.	Prob.
Breusch-Pagan LM	16.70113	10	0.0812
Pesaran scaled LM	0.380384		0.7037
Bias-corrected scaled LM	0.067884		0.9459
Pesaran CD	1.563098		0.1180

Source: Eviews result, 2023

B6. Im-Pesaran-Shin unit-root test for the panel data model

Table 13: Unit root test

Levin-Lin-Chu unit-root test							
Ho: Panels contain unit roots	ADF regressions: 1 lag						
Ha: Panels are stationary	LR variance: Bartlett kernel, 6.00 lags average (chosen by LLC)						
	Level			First difference			Order
Variables	Unadjusted t	Adjusted t*	P-Value	Unadjusted t	Adjusted t*	P-Value	
LNPEE	-1.8041	-1.8352	0.0332	-20.6114	-20.9081	0.0000	I(0)
LNGDP	-2.7216	-1.0507	0.1467	-7.5605	-4.3484	0.0000	I(1)
LNGDPSQR	-1.3866	0.3621	0.6414	-5.5186	-2.6073	0.0046	I(1)

Source: Stata result, 2023

B7. Serial correlation

Table 14: Autocorrelation test

```
Wooldridge test for autocorrelation in panel data
H0: no first-order autocorrelation
    F(  1,        4) =     128.903
           Prob > F =       0.0003
```

Source: study result (2023)

B8. Specification error test

Table 15: Ramsey model specification test

```
==============================================================================
*** REgression Specification Error Tests (RESET) - Model= (xtfe)
==============================================================================
 Ho: Model is Specified  -  Ha: Model is Misspecified
------------------------------------------------------------------------------
* Ramsey Specification ResetF Test
- Ramsey RESETF1 Test: Y= X Yh2         = 131.258  P-Value > F(1,  40) 0.0000
- Ramsey RESETF2 Test: Y= X Yh2 Yh3     =  65.749  P-Value > F(2,  39) 0.0000
- Ramsey RESETF3 Test: Y= X Yh2 Yh3 Yh4 =  43.809  P-Value > F(3,  39) 0.0000
------------------------------------------------------------------------------
* DeBenedictis-Giles Specification ResetL Test
- Debenedictis-Giles ResetL1 Test       =   2.234  P-Value > F(2, 39)  0.1206
- Debenedictis-Giles ResetL2 Test       =   2.119  P-Value > F(4, 37)  0.0980
- Debenedictis-Giles ResetL3 Test       =   1.471  P-Value > F(6, 35)  0.2165
------------------------------------------------------------------------------
* DeBenedictis-Giles Specification ResetS Test
- Debenedictis-Giles ResetS1 Test       =   1.766  P-Value > F(2, 39)  0.1845
- Debenedictis-Giles ResetS2 Test       =   2.691  P-Value > F(4, 37)  0.0459
- Debenedictis-Giles ResetS3 Test       =   1.758  P-Value > F(6, 35)  0.1366
------------------------------------------------------------------------------
- White Functional Form Test: E2= X X2  =  30.982  P-Value > Chi2(1)   0.0000
------------------------------------------------------------------------------
```

Source: study result (2023)