



Research article

Human activities and environmental quality: evidence beyond the conventional EKC hypothesis[☆]

Sisay Demissew Beyene

College of Business and Economics, Department of Economics, Arsi University, Asella, Ethiopia

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ABSTRACT

Due to several types of human activities, the environment of African countries has not improved. Moreover, environmental economists have criticised the traditional Environmental Kuznets Curve (EKC) hypothesis because it does not analyse the feedback effect of the environment on economic growth and does not measure environmental pollution broadly. Besides, empirical studies that comprehensively measure the environment and examine the feedback effect are not available in Africa's case. In addition, findings concerning the association between human activities and Environmental Quality (EQ) have been paid limited attention to Africa, although 50% of the Sustainable Development Goals (SDGs) focus on these issues. Therefore, this study examines the link between human activities and EQ as well as the effect of EQ on growth for 38 African countries from 2000 to 2018. The study found that EQ has a positive and non-linear association with human capital, technology, and urbanisation. However, it has a negative and non-linear association with GDP Per Capita (GDPPC) and trade openness. Further, EQ significantly increases GDPPC. The study also recommends that African countries need to invest in improving Human Development Index (HDI), use green or low-carbon technologies, reduce migration from rural to urban, develop comprehensive urban planning, and design and implement appropriate trade policies.

1. Introduction

The association between economic growth and environmental pollution is an inverted U-shape, which is explained by the conventional EKC hypothesis (Grossman and Krueger, 1993; Panayotou, 1993; Halkos and Managi, 2016, 2017). However, researchers expanded the EKC model to include more human activity¹ variables. Nonetheless, the EKC has been criticised mostly for emphasising the connection between these factors and particular types of pollution. Relying on certain pollutants cannot adequately explain the link between EQ and human activities. Esty et al. (2005) noted that a single or a small number of pollution indexes could not adequately represent EQ, since EQ can be impacted by various pollutants, including air, water, and solid pollution. Hence, examining the association between human activities and EQ is essential to comprehend and extract sound and broad policy implications.

Figures 1 and 2 illustrate the association between EQ and human activities. According to Figure 1, in the past 19 years, the EQ improved by only two indices. However, urbanisation and GDPPC increased at a higher rate. Even though international trade fluctuated, its growth rate was higher than Environmental Performance Index (EPI). This implies that trade, urbanisation, and GDPPC have a determinant effect on

Africa's environmental quality. However, as seen in Figure 2, EPI has been positively linked with Human Development Index (HDI) and Technology (TECH) in Africa, especially since 2011.

Since income is considered an exogenous variable, the EKC hypothesis is also subject to the theoretical criticism that it presumes no spillover from environmental pollution to economic growth. In other words, it is anticipated that the economy is strong and that any irreversibility will not significantly impact future income levels. This presumption is unreasonable, as attempting to grow too quickly during the earliest stages of growth while environmental degradation rises may be counterproductive if the economy is not sustainable (Panayotou, 1997). Besides, resource overuse and ecological damage can impact economic growth. Thus, the long-term viability of an economy is constrained by resource exhaustibility (Lopez, 1994; Chaabouni and Saidi, 2017; Shao et al., 2019). Cass (1965) also noted that people's desire for EQ rises with economic development, impacting economic growth. Further, in most circumstances, pollution has a positive marginal production and a negative marginal utility (Selden and Song, 1994; Chang et al., 2019). The economy and environment are also determined together (Perrings, 1998). Hence, estimating a single equation model of the economy's effect on the environment is inefficient. When the environment has

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¹ Knowledge (education or human capital), foreign trade, urbanisation, population, and technology or energy consumption.

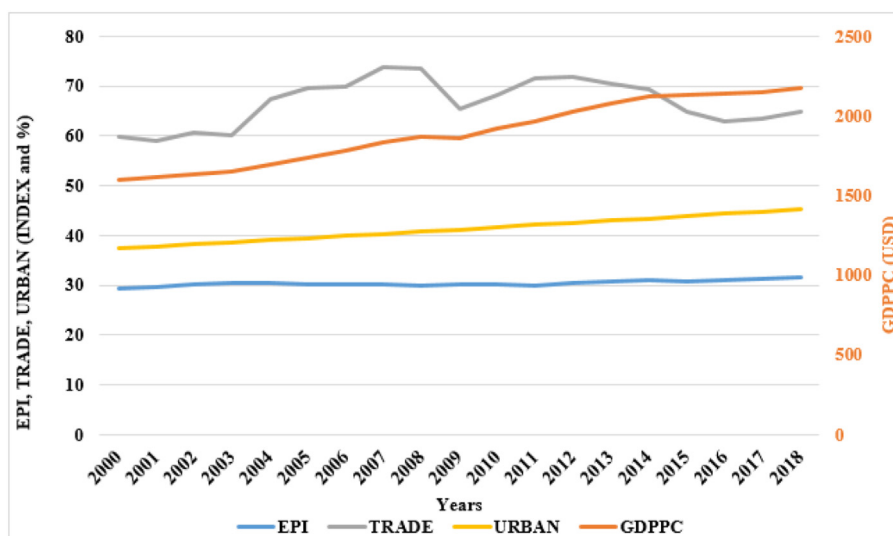


Figure 1. Trends of EPI, international trade (TRADE), urbanization (URBAN), and GDPPC from 2000 to 2018 in Africa. Source: Constructed by the author using data sources described in Table 2.

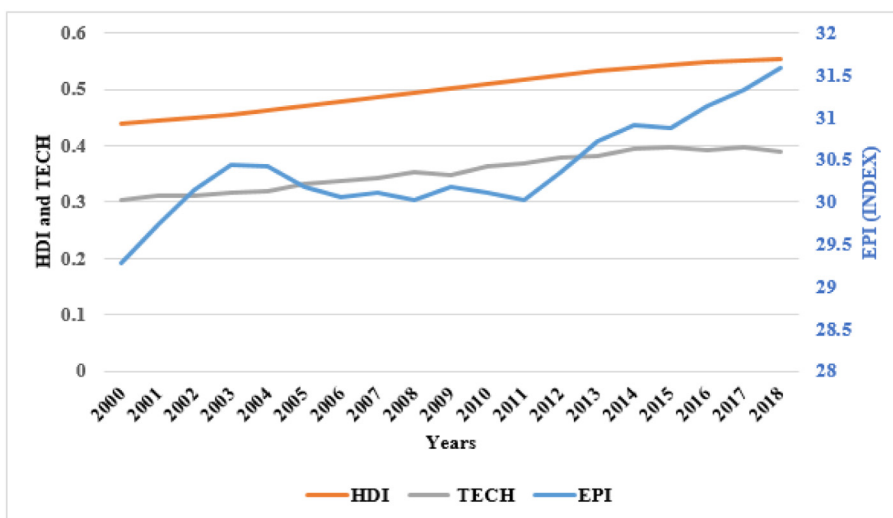


Figure 2. Trends of EPI, HDI, and TECH from 2000 to 2018 in Africa. Source: Constructed by the author using data sources described in Table 2.

deteriorated in many developing countries, rapid economic expansion may be unproductive and unsustainable (Barbier, 1994). As a result, the Simultaneous Equations Model (SEM) method, rather than a single equation model, can better explain the interaction between the environment and economic progress (one of the human activities).

Several studies have used SEM in the context of non-African nations, including Khan et al. (2019), Jiang et al. (2020), Malik (2021), Li and Xu (2021), and Kumar and Datta (2021). A comprehensive and in-depth analysis of the relationship between EQ and economic growth is not provided by analysing the relationship between economic growth and the environment. Therefore, understanding the connections between the variables is crucial for creating a solid policy framework. To the best of the author’s knowledge, however, empirical results that used SEM to evaluate the association between human activities, EQ, and growth are not accessible in Africa, leaving methodological and literature gaps.

Though there are many linear as well as non-linear empirical findings on the link between urbanisation, economic growth, technology, trade openness, and the environment under conventional EKC, their results are

mixed and ambiguous (for more detail, see Munir and Ameer, 2021). In addition, only Sultana et al. (2021) expanded on the earlier research by considering human capital as another independent variable, though they used Bangladesh as a case study. This suggests that, to the best of the author’s knowledge, no study has shown the non-linear relationship between human activities and EQ (as measured broadly) in Africa, resulting gap in the literature. Thus, this study examines the non-linear impact of human capital, economic growth, trade openness, urbanisation, and technology on the EQ in the African context.

This article adds to the literature in several ways. First, it concentrates on Africa, where studies are lacking despite the fact that half of the SDGs are focused on human activities, sustainable economic growth, and environmental sustainability challenges. Second, unlike the conventional EKC, which focused on how specific environmental pollutants changed with economic expansion, this study examines how EQ changes with various human activities, providing a more comprehensive knowledge of the interaction between human activities and the environment. Third, this study employs reliable estimating methods (Seemingly Unrelated

Table 1. Empirical literature.

Author	Model	Scope	Results
Antweiler et al. (2001)	Fixed effect (FE), Random effect (RE), & two-stage least squares (2SLS)	From 1971 to 1996, 109 cities in 44 countries	Free trade affects the environment, although not all countries experience the same effects.
Cole and Neumayer (2004)	Ordinary least squares (OLS) & Panel-correlated standard errors (PCSE)	From 1977 to 1990, 86 countries	URBAN \uparrow carbon-di-oxide (CO ₂) emissions, but the relationship between population & sulphur dioxide (SO ₂) emission is U-shape.
Khalil and Inam (2006)	Error correction model (ECM)	From 1972 to 2002, Pakistan	International trade (IT) negatively impacts the environment
Lean and Smyth (2010)	Dynamic OLS (DOLS) & Granger causality	From 1980 to 2006, five Asian countries	CO ₂ & energy consumption have a +ve association, whereas CO ₂ & economic development have a non-linear relationship.
Hossain (2011)	Granger causality & Generalised Method of Moment (GMM).	From 1971 to 2007, nine countries	Energy consumption \uparrow CO ₂
Kleemann and Abdulai (2013)	FE with Driscoll & Kraay standard errors	From 1980 to 2003, high & low-income countries	Free trade \uparrow CO ₂ in low-income countries.
Shahbaz and LeitA (2013)	OLS, the regression with Newey-West standard errors, & autoregressive moving average.	From 1970 to 2009, Portugal	IT \uparrow CO ₂
Chandran and Tang (2013)	Vector ECM (VECM) & Granger causality	From 1971 to 2008, five Asian countries	Energy consumption in the transportation sector & economic growth \uparrow CO ₂
Akin (2014)	Fully Modified OLS, DOLS, & causality analysis	From 1990 to 2011, 85 countries	Trade openness (OPN), energy consumption, & economic growth \uparrow CO ₂
Bernard and Mandal (2016)	GMM	From 2002 to 2012, 20 emerging and developing countries	Government effectiveness, political, globalisation, & economic growth \uparrow EQ, whereas GDPPC \downarrow CO ₂ .
Kais and Sami (2016)	GMM	From 1990 to 2012, 58 countries	Energy use \uparrow CO ₂ , while GDPPC & CO ₂ have an inverted u-shape relationship
Al-Mulali and Ozturk (2016)	FMOLS & vector ECM, Granger causality	From 1990 to 2012, 27 advanced economies	CO ₂ \uparrow ed by GDP, non-renewable energy consumption, URBAN, whereas they are \downarrow ed by renewable energy consumption, TO, & energy pricing. Furthermore, GDP & CO ₂ have an inverted U-shaped relationship.
Kang et al. (2016)	Spatial econometrics model	From 1997 to 2012, China	CO ₂ is \uparrow ing due to URBAN & coal combustion, whereas it \downarrow ed due to OPN.
Dogan and Turkekul (2016)	Autoregressive Distributed Lag (ARDL) & Granger causality	From 1960 to 2010, USA	Energy consumption & URBAN \uparrow CO ₂ , but ONP \downarrow it.
Li et al. (2016)	System GMM & panel ARDL	From 1996 to 2012, China	Energy consumption, URBAN, & OPN \uparrow pollution
Wang et al. (2016)	Parametric & non-parametric analysis	From 1990 to 2012, provinces in China	Inverted U-shape relationship between SO ₂ and economic growth
Chowdhury and Islam (2017)	Correlation analysis	From 2002 to 2013, BRICS	-ve association between economic growth & EQ.
Saboori et al. (2017)	Granger causality, Johansen cointegration test, GIRF & variance decompositions	From 1980 to 2013, China, South Korea & Japan	In China: Economic growth and CO ₂ as well as economic growth and oil consumption, have a -ve relationship. On the other hand, urban population growth, economic growth, and OPN have positive long-term associations. In Japan, the long-term associations between economic growth and oil consumption are -ve, but those between economic growth and OPN, and urban population growth are +ve.
Munir and Ameer (2018)	Panel cointegration & causality test	From 1980 to 2014, 11 countries	OPN & technology have a +ve impact on SO ₂ ; however, URBAN has a -ve impact; inverted U-shape association between SO ₂ and economic growth.
Bano et al. (2018)	ARDL & causality analysis	From 1971 to 2014, Pakistan	Long-term casual association between human capital and carbon emission.
Rasoulinezhad and Saboori (2018)	DOLS, FMOLS, & Dumitrescu-Hurlin causality	1992–2015, Commonwealth countries	Except for economic growth-renewable energy use linkage, there is a bidirectional long-run relationship between renewable & non-renewable energy consumption, economic growth, CO ₂ , composite trade intensity, & financial openness.

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Table 1 (continued)

Author	Model	Scope	Results
Khan et al. (2019)	SUR & three-stage least squares (3SLS)	From 1970 to 2017, 193 countries	Economic growth, energy consumption, and carbon emissions influence one another, with considerable energy spread, except for energy consumption (which ↓ is financial development). All models confirm EKC.
Munir and Riaz (2019)	PMG & Granger causality	From 1985 to 2017, three countries	Electricity & coal consumption affect CO ₂ non-linearly
Saleem and Shujah-ur-Rahman (2019)	Dynamic SUR	From 1991 to 2014, BRICS	Bidirectional causality among human capital, economic growth, & environmental pollution.
Sarwar et al. (2019)	GMM	2000–2016, 161 countries	Human capital has an insignificant impact on environmental pollution & economic growth.
Ahmed and Wang (2019)	ARDL, FMOLS, DOLS, canonical cointegrating regression, VECM	From 1971 to 2014, India	Environmental footprint ↓ due to human capital.
Li and Ouyang (2019)	ARDL	From 1978 to 2015, China	The association between human capital and carbon emission intensity is inverted N-shaped.
Bashir et al. (2019)	VECM-based Granger causality	From 1985 to 2017, Indonesia	Causality runs from human capital to CO ₂ in the short run
Rahman et al. (2019a)	Dynamic SUR GMM & GMM	From 1991 to 2014, Central & Eastern European countries	N-shaped relationship between economic growth and footprint, energy consumption and financial development contribute to environmental pollution & human capital adversely affects the environment.
Munir and Riaz (2020)	Non-linear ARDL & Granger causality	From 1975 to 2018, Australia, China, & USA	Energy use & CO ₂ have a non-linear relationship.
Yao et al. (2020)	OLS, augmented mean-group, PMG & 2SLS	From 1870 to 2017, 20 OECD countries	The association between human capital and CO ₂ is –ve.
Khan (2020)	Hansen threshold	From 1980 to 2014, 122 countries	More schooling ↑ CO ₂ when human capital is low. But, beyond a certain point, it starts to ↓ CO ₂ .
Abdoul and Omir (2020)	DOLS & FMOLS	From 1990 to 2013, Mediterranean region countries	Bidirectional causality between human capital, CO ₂ , economic growth & FDI.
Kim and Go (2020)	2SLS	72 countries	Human capital improves the environment.
Jiang et al. (2020)	3SLS	From 2006 to 2016, 286 cities in China & 22 cities & countries in South Korea	While non-metropolitan areas have a U-shaped relationship between economic growth and air pollution in both countries, metropolitan areas have an inverted U-shaped relationship. Urban areas in China have higher levels of pollution than rural areas; however, this is not the case in Korea. While the southwest, central, and northeast parts of China have U-shaped relationships, the eastern and northwest regions of China have an inverted U-shaped relationship.
Khan et al. (2021)	Cross-sectional augmented ARDL	From 1990 to 2018, seven OECD countries	Human capital ↑ EQ. CO ₂ is caused by one-way causation from fiscal decentralisation, human capital, & GDP.
Li and Xu (2021)	3SLS	From 2004 to 2017, China	Inverted U-shape relationship between human development and environmental pollution. IT ↑ EQ and investment in physical and human capital ↑ the economy, where as pollution ↓ the economy.
Cakar et al. (2021)	Panel smooth transition regression	From 1994 to 2018, 21 EU countries	In low human capital regimes, carbon emissions ↑, and vice versa
Sultana et al. (2021)	ARDL & FMOLS	From 1972 to 2018, Bangladesh	URBAN and economic growth result in ecological footprints. Supports EKC.
Malik (2021)	GMM & 3SLS	From 1970 to 2014, Turkey	Causality between economic growth & energy consumption, CO ₂ & economic growth, CO ₂ & energy consumption is bidirectional. Besides, the association between CO ₂ & economic growth is rising monotonically.
Kumar and Datta (2021)	FE-2SLS & RE-2SLS	From 1990 to 2015, 59 countries	While forest area hurts GDPPC & GHG emissions, organic water pollution (OWP), greenhouse gas emissions (GHG), and metal & ore export (EX) all have a positive

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Table 1 (continued)

Author	Model	Scope	Results
			effect on the economy. On the other side, economic expansion increases GHG for middle-class households and OWP for higher-income households. Furthermore, in higher and middle-income groups, EX positively correlates with GHG.
Musibau et al. (2021)	2SLS, quantile	From 2006 to 2018, Economic Community of West Africa states	The association between economic growth & environmental performance, economic growth and government size, & economic growth & OPN is bidirectional. Moreover, the environment, government size, labor, & capital stock + vely affect the economy, whereas ONP has –ve effect.

Source: constructed by the author

Cointegration (SUR) and panel quantile) that protect against Cross-sectional Dependency (CD), serial correlation, and endogeneity problems. Fourth, it also sheds light on how the variables are related, improving the results' precision and policy recommendation. Fifth, it takes into account the reciprocal relationship between economic growth and the environment (it looks at how the environment affects growth through feedback). Sixth, the study expands on earlier panel data analyses by including a human capital element. Lastly, it considers fundamental panel econometric tests, which allow for the production of reliable results and recommendations for action.

2. Literature review

2.1. Environmental pollution theories

The IPAT model, developed by Ehrlich and Holdren (1971), defines and quantifies the environmental impacts(I) of the population (P), affluence (A) (per capita production or consumption), and technology (T). Additionally, the traditional EKC hypothesis analyses the connection between pollutants and economic growth. The background research by Shafik and Bandyopadhyay (1992) for the World Development Report in 1992 was the basis for the EKC concept (Beyene and Kotosz, 2020). The EKC hypothesis states that EQ is worse in the early stages of economic growth but improves as the economy strengthens. Using the EKC hypothesis, Grossman and Krueger (1991, 1995) confirmed an inverted U-shaped relationship between per capita income and environmental degradation (Beyene and Kotosz, 2020).

The association between international trade and the environment is also explained by the Hecksher-Ohlin trade theory. During free trade, developed nations specialise in human capital and manufacture capital-intensive activities, whereas developing countries concentrate on labour and natural resource-intensive activities. Therefore, countries make use of comparative advantage in pollution. This suggests that pollution is produced throughout the production process and is connected to other nations' consumption. Thus, the pollution haven hypothesis states that trade may benefit some countries' environments while harming those of nations (Frankel, 2009; Halicioglu and Ketenci, 2016). Moreover, the race to bottom as well as the gains from trade are two opposing hypotheses on the impact of investment and trade on the environment. According to the race to the bottom theory, investment and international trade can reduce nation's environmental standards, causing harm to the global environment. However, the gains from trade hypothesis hold that there are possibilities that trade openness and investment can improve the environment by encouraging innovations and environmental standards (Frankel, 2009).

Similarly, Zhao et al. (2021) noted two theories regarding the association between technology and the host country's environmental damage. First, according to the pollution haven theory, introducing technology would be detrimental to the environment of the host nation (Markusen and Venables, 1999; Sapkota and Bastola, 2017; Rahman et al., 2019b). The pollution halo hypothesis, however, contends that the

host country's environment would be improved by the demonstration effect of new technology and the host country's learning effect (Zhang and Zhou, 2016; Repkine and Min, 2020).

Based on the pollution haven hypothesis, most scholars have focused on examining the relationship between the strength of environmental regulation and Foreign Direct Investment (FDI) location choice or the association between FDI and pollution. However, recently some scholars have argued that the process of FDI's impact on the host environment is multifaceted and not as straightforward as the pollution haven hypothesis states; rather, it is influenced by the degree of human capital (Gao, 2016). According to Lan et al. (2012), Li and Liu (2012), and Yan and Lu (2014), FDI tends to reduce emissions in countries with high human capital, while FDI tends to degrade EQ in areas with limited human capital. This implies that the pollution haven hypothesis incorporates how FDI affects the environment from the perspective of human capital. Besides, the emissions emancipated human development index (eHDI) has recently become popular in economic literature. It refers to the relationship between the environment and human efforts to improve health, education, and income (Zaman and Abd-el Moemen, 2017).

2.2. Empirical literature

For the sake of scope, this section offers empirical evidence that emphasizes the effects of technology (energy consumption), urbanisation, trade openness, human capital, and other factors on the environment, as well as the impact of the environment on growth.

Table 1 demonstrates that, with the exception of a few studies, the majority of research is outdated; hence, their findings and any policy ramifications are not applicable and thus not helpful in the contemporary world. Additionally, some of the research in Table 1 is country-specific. However, one country's outcomes and policy ramifications do not accurately characterise other countries'. Despite the fact that several studies employed panel data for a collection of countries, their sampled nations were small.

All studies used a single or particular emission indicator to measure EQ. However, EQ was measured using a broad indicator by Musibau et al. (2021), Kim and Go (2020), and Chowdhury and Islam (2017). Li and Xu (2021) performed an alternative measurement of EQ via the environmental deterioration index using just six indicators. Comparatively speaking, the current study provides a detailed investigation because it evaluates EQ broadly (including 32 indicators and 11 issue categories). This study also takes into account the environment's feedback effect on growth as well as fundamental econometric tests.

Concerning methodology, the majority of studies, except a few, do not apply robust estimation approaches (SEM) or take into account basic econometric tests. In addition, the existing research, except for Khan et al. (2019), Li and Xu (2021), and Kumar and Datta (2021) employ a single model and ignore the feedback analysis. Furthermore, even though the studies mentioned above use SEM, they employ only one pollution indicator, overlook fundamental econometric tests, and use a linear model (like Kumar and Datta (2021)). The current study, however, uses a

Table 2. Variables and sampled countries information.

Variable	Measurement and definition	Source
EPI	An environmental performance index is a proxy of EQ is measured (0–100)	YCELP
HDI	Proxy for human capital is measured by the average performance in three critical areas of human development: living a long and healthy life, knowledge, and good living standards.	UNDP
HDI ²	HDI Square	
GDPPC	GDP per capita (2015 constant USD) is a measure of economic growth	WDI
GDPPC ²	GDPPC square	
OPN	Trade openness as a percentage of GDP is a proxy for international trade	
OPN ²	OPN square	
URBAN	Urbanisation measured as urban population as a percentage of the total population	
URBAN ²	URBAN square	
GCFPC	Gross capital formation per capita measured in USD	
LAB	Labor force as a percentage of the total population	
TECH	Technology, a proxy of energy consumption (tonne of oil equivalent) per capita	U.S energy information administration—international energy statistics database
TECH ²	TECH square	

Sampled countries: Algeria, Angola, Benin, Botswana, Burkina Faso, Burundi, Cameroon, Central Africa Republic, Chad, Comoros, Cote d'Ivoire, Dem. Rep. Congo, Egypt, Gabon, Gambia, Ghana, Guinea, Kenya, Liberia, Madagascar, Mali, Mauritania, Mauritius, Morocco, Namibia, Niger, Republic of Congo, Rwanda, Senegal, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Tunisia, Uganda, and Zimbabwe.

Source: Constructed by the author

Table 3. Descriptive statistics of the variables.

Variable	Obs	Mean	Std. Dev	Min	Max	Skewness	Kurtosis
EPI	722	30.400	5.445	19.356	45.365	0.632	2.911
HDI		0.499	0.114	0.262	0.801	0.449	2.57
GDPPC		1894.904	1954.812	281.970	10335.85	1.736	5.474
OPN		66.703	31.746	16.141	311.354	2.275	15.012
URBAN		41.245	16.412	8.246	89.37	0.378	2.877
TECH		0.355	0.526	0.0085	2.840	2.630	10.738
GCFPC		678.857	1785.187	1.521	20625.83	6.976	61.255
LAB		38.332	6.415	23.501	51.055	-0.0032	2.306

Source: computed by the author using Stata 15

reliable estimation method along with fundamental econometric tests and feedback analysis.

3. Methodology of the study

3.1. Data type and sources

This study uses panel data from international institutions such as the Yale Center for Environmental Law and Policy (YCELP), World Development Indicators (WDI), and United Nations Development Program (UNDP). The data type, sources, and sampled countries are presented in Table 2. The sampled countries are 38 African nations and were chosen based on the existing research gaps described in previous sections as well as data availability. Moreover, the sampled countries can accurately represent the continent since they come from all African regions (North, Central, East, South, and West). Finally, around 90% of sampled countries represent sub-Saharan African countries where environmental pollution increases over time, raising policymakers' concerns.

The YCELP has broadly categorised the EQ indicator into three: Environmental Performance Indicator (EPI), Environmental Health (EH), and Ecosystem Vitality (EV). EV and EH share 60% and 40% of

² Air quality, sanitation and drinking water, heavy metals, and waste management.

³ Biodiversity and habitat, ecosystem service, fisheries, climate change, pollution emissions, agriculture and water resources.

EPI, respectively, and are components of EPI. Further, 32 indicators and 11 issue categories contribute to EPI through EH² and EV³ (policy objectives). Since EPI is broad and captures the others, this study uses it as a proxy variable for EQ. The number of countries and elements included in measuring the EPI varies. For instance, in 2016 there were 20 indicators, nine issue categories, and two policy objectives; in 2018 there were 24 indicators, ten issue categories, and two policy objectives; and in 2020 there were 32 indicators, 11 issue categories, and two policy objectives. Therefore, this study calculated EPI based on the recent YCELP 2020 weight values. To fill the EPI's missing data for the years 2011, 2013, 2015, and 2017, instead of interpolation and to increase sampled countries and observations, which helps to attain the asymptotic properties of an estimator (Kennedy, 2008), this study calculated all EPI's from 2000 to 2018 based on YCELP 2020 EPI framework weights (values).

3.2. Descriptive statistics of the variables

Table 3 presents the descriptive statistics of the model's variables. The mean of EPI is 30.4 and the range is between 19.35 and 45.36, indicating insignificant variation. Likewise, HDI's has a small variation in its range. However, GDPPC ranges between 281.97 and 10,335.85, which is high because it is measured as USD. Likewise, GCFPC has a broad range between 1.521 and 20,625.83. As the skewness and kurtosis results show, all variables have positively skewed except for LAB. Besides, the kurtosis of all variables ranges between 2.3 and 61.255.

3.3. Theoretical framework, model specification, and estimation approaches

For the EQ model, this study adapted the stochastic version of the IPAT (STIRPAT) model developed by Dietz and Rosa (1994) and recently used by several scholars, such as York et al. (2003), Wang et al. (2016), Munir and Ameer (2018, 2020), and Sultana et al. (2021). The STIRPAT evaluates the combined effects of population growth, affluence, and technological advancement on the environment (York et al., 2003). Hence, the panel data STIRPAT model is shown in Eq. (1) below:

$$I_{it} = \alpha P_{it}^{\theta_1} A_{it}^{\theta_2} T_{it}^{\theta_3} \mu_{it} \tag{1}$$

where I indicates environmental impact, p refers to population, A relates to affluence, T indicates to technological, and μ_{it} indicates the stochastic error term. Moreover, *i* and *t* refers to cross-section and time, respectively ($i = 1, \dots, N, t = 1, \dots, T$), and $(\theta_1 - \theta_3)$ represents exponents.

This study investigates the association between human activities and the environment in African countries. Thus, it broadens Munir and Ameer's (2021) analysis by adding human capital and specifying the estimated model as shown in Eq. (2):

$$EQ_{it} = \overbrace{\alpha HC_{it}^{\alpha_1} GDPPC_{it}^{\alpha_2} OPN_{it}^{\alpha_3} URBAN_{it}^{\alpha_4} TECH_{it}^{\alpha_5}}^{\text{human activities}} \mu_{it} \tag{2}$$

where HC represents human capital.

Further, this study aims to investigate the non-linear relationship; it thus indicates the quadratic term of human activity variables (following Munir and Ameer (2021) and human capital (following Li and Xu (2021)) in Eq. (2).

Unlike the traditional EKC, this study considers the feedback effect of EQ on economic growth. Ayres and Kneese (1978) and Considine and Larson (2006) introduced the environment as one more factor of production, in addition to the traditional factors of capital and labour. Thus, the theoretical framework of this study is the extended neoclassical growth model of Solow (1956) and Swan (1956). Besides, it follows Musibau et al. (2021) and Li and Xu (2020), employs the linear transformed Cobb-Douglas production function, and includes EQ to examine the feedback impact of the environment on growth. Therefore, Eqs. (3) and (4) are the two econometric models this study employs.

$$EQ_{it} = \alpha_0 + \alpha_1 HC_{it} + \alpha_2 HC_{it}^2 + \alpha_3 OPN_{it} + \alpha_4 OPN_{it}^2 + \alpha_5 GDPPC_{it} + \alpha_6 GDPPC_{it}^2 + \alpha_7 URBAN_{it} + \alpha_8 URBAN_{it}^2 + \alpha_9 TECH_{it} + \alpha_{10} TECH_{it}^2 + \mu_{it} \tag{3}$$

$$GDPPC_{it} = \beta_0 + \beta_1 EQ_{it} + \beta_2 GCFCPC_{it} + \beta_3 LAB_{it} + \varepsilon_{it} \tag{4}$$

where $\alpha_0 - \beta_0$ indicates intercept terms, ε_{it} refers to error terms, $\alpha_1 - \alpha_3$ and $\beta_1 - \beta_3$ and refers to estimated parameters.

Eqs. (3) and (4) constitute the SEM that this study uses to evaluate human activities' effect on EQ and the impact of EQ on growth. Since this study uses EPI to measure EQ and HDI as a proxy for human capital, the SEM is specified in Eq. (5) below:

$$\begin{cases} EPI_{it} = \alpha_0 + \alpha_1 HDI_{it} + \alpha_2 HDI_{it}^2 + \alpha_3 GDPPC_{it} + \alpha_4 GDPPC_{it}^2 \\ + \alpha_5 OPN_{it} + \alpha_6 OPN_{it}^2 \dots \\ + \alpha_7 URBAN_{it} + \alpha_8 URBAN_{it}^2 + \alpha_9 TECH_{it} + \alpha_{10} TECH_{it}^2 + \mu_{it} \\ GDPPC_{it} = \beta_0 + \beta_1 EPI_{it} + \beta_2 GCFCPC_{it} + \beta_3 LAB_{it} + \varepsilon_{it} \end{cases} \tag{5}$$

The following are the justifications for why the variables were added to the models mentioned above.

EPI: For the EQ model, this variable is utilised as a proxy for environmental quality and dependent variable, while it is an independent variable for the growth model. Therefore, the current study employs EPI because it seeks to reflect the environment through broad indicators rather than just one.

GDPPC: is a proxy variable of economic growth. It is used as a dependent variable for the growth model and an independent variable for EQ model. It is a crucial and fundamental variable in EQ model to explain the EKC hypothesis.

HDI: serves as a proxy for development in human capital and an independent variable in the EQ model. A rise in human development raises society's educational standards, and those with higher education standards better living conditions (Li and Xu, 2021). Additionally, by applying green technologies, development in human capital can increase efficiency and productivity while creating a positive relationship between the environment and human beings (Bano et al., 2018; Ahmed and Wang, 2019).

OPN: Is an independent variable and is employed as a proxy for nations' import and export activities. The race to the bottom hypothesis, in addition to the trade theory of Hecksher-Ohlin outlined in the previous section, claims that countries' environmental standards can decline due to international trade and investment, harming the global environment. Some scholars, however, contend that OPN and investment may improve EQ by encouraging innovations and boosting environmental norms (Frankel, 2009). Additionally, according to Nazir et al. (2018), OPN can affect the environment through scale, composition, and technique effects.

URBAN: is used as a proxy for urban development. There are two arguments on how urbanisation affects the environment. First, urbanisation and urban infrastructure systems adversely affect the environment (for more details, see Pata, 2018). The second is that urbanisation can help the environment (for more information, see Wan and Kahn, 2014).

TECH: there are two theories regarding the connection between technology and the host country's environmental conditions (Zhao et al., 2021). According to the pollution haven theory, an introduction of technology will harm the environment of the host nation (Rahman et al., 2019b). However, the reverse holds true under the pollution halo hypothesis (Repkine and Min, 2020).

LAB and GCFCPC are explanatory variables that serve as stand-ins for labor force and capital accumulation. This study uses the neoclassical Solow (1956) and Swan (1956) growth model as a theoretical foundation for claiming that labour and capital are the primary factors of production.

Basic econometric tests (CD, unit root, and cointegration) must be carried out prior to model estimation (for more details, see Beyene and Kotosz, 2021; Beyene, 2022). Even though there are several CD tests, this study employs Pesaran's (2021) and Frees's (1995) tests. This is because, in contrast to Breusch and Pagan's (1980) Lagrangian multiplier test, they do not necessarily need fixed cross-section countries (N) and infinite time-series (T); instead, they suit with large N and T. Besides, Frees's test can solve the problem of irregular signs related with correlation. Moreover, since the first-generation unit root tests cannot be applied when there is CD, the current study employs an alternative (the second-generation) panel unit root test called Pesaran's (2007) CIPS to test all variables stationarity (unit root). Further, the current study uses Banerjee and Carrion-i-Silvestre's (2017) cointegration test.

After basic panel econometric tests, this study uses SEM to estimate the models. Though many panel estimation approaches⁴ support CD, most are not programmed in both Stata and EViews or do not estimate the models simultaneously.

However, SEM estimates the models simultaneously and captures the data's dynamic behaviour. In addition, due to a bidirectional relationship between EQ and economic growth, endogeneity problems may arise; however, SEMs can solve this problems (Jiang et al., 2020; Li and Xu, 2021). Besides, SEM safeguards the regression against serial correlation. Moreover, the SEM provides detailed variables relationship (Li and Xu, 2021), increasing the precision of the estimated outcomes and policy

⁴ Cross-section-ARDL, cross-section-distributed lag, common correlated effects pooled, common correlated effect mean group, continuously updated full modified, continuously updated bias corrected, Driscoll and Kraay (1998) standard error, PCSE, and feasible generalised least squares.

Table 4. CD, unit root, and cointegration results.

CD tests			
CD tests	Models	Stat.	
Pesaran test	EPI model	−1.788*	
	Growth model	23.712***	
Frees test	EPI model	7.202***	
	Growth model	11.040***	
Pesaran's (2007) unit root test			
Variables	Levels	1st diff.	2nd diff.
	Stat.	Stat.	Stat.
EPI	−1.963	−3.118***	
HDI	−2.546*	−3.708***	
HDI ²	−2.441	−3.708***	
GDPPC	−1.682	−3.882***	
GDPPC ²	−1.342	−3.706***	
OPN	−2.495	−3.946***	
OPN ²	−2.613*	−4.284***	
URBAN	−0.769	−1.778	−3.542***
URBAN ²	−1.179	−1.398	−3.172***
TECH	−2.428	−4.137***	
TECH ²	−2.061	−3.785***	
GCFPC	−2.199	−4.023***	
LAB	−1.292	−2.258	−3.930***
Panel cointegration test			
Banerjee and Carrion-i-Silvestre (2017)		Models	Levels Statistic
Excluding squares of independent variables due to an insufficient number of observations		EPI model	−4.005***
For all variables		Growth model	−2.909***

* = significant at the 10% *** = significant at the 1% level.

Source: Computed by the author employing Stata 15.

recommendations. Furthermore, measurement errors and omitted variables are sources of endogeneity problems. Concerning this, most macroeconomic variables of African countries are not measured accurately. For instance, due to informal economic activities and the lack of a structured labour market, GDP and unemployment levels are not measured correctly. However, SEM considers that both endogenous and exogenous variables have no measurement error (Paxton et al., 2011). Regarding omitted variables, Leff and Sato (1975) argue that most of the econometric analyses of saving in developing nations have employed single-equation models. However, the relationship between saving (S) and investment (I) is $S = I - F$, where F represents foreign capital inflows. Therefore, it is vital to consider the simultaneous determination of S and I to prevent bias in estimated parameters.

Therefore, this study employs the SUR model among the existing⁵ SEMs (see Beyene and Kotosz, 2021) to understand SUR in detail. The rationale for the primary use of SUR relative to other SEMs is that it allows CD. Moreover, GMM provides short-run results instead of long-run.

However, the study uses 2SLS, 3SLS, and Multivariate Regression (MVREG) for robustness checks. The 2SLS, introduced by Theil (1992), is the general method for SEM. The 3SLS, developed by Zellner and Theil (1992), is more robust than the 2SLS because it considers the simultaneous correlation of disturbances across the SEM equations. Furthermore, according to Kennedy (2008), 3SLS is thought to be more reliable and efficient than 2SLS; hence, it is recommended over 2SLS when there are correlations between various equations disturbances. However, since 2SLS, 3SLS, and MVREG approaches are not the basic estimation technique for this study; instead, they are used for robustness checks.

Despite the fact that most researchers commonly use panel regressions, the conclusions and policy implications drawn from them might have some limitations (Cade and Noon, 2003) because they offer information on the mean value rather than the dependent variable's conditional distribution (Nkengfack et al., 2019). Hence, the quantile estimation is recommended, which was introduced by Koenker and Basset (1978) and improved by Koenker and Machado (1999) and Koenker and Hallock (2001) (for more detail, see Beyene, 2022). To save space, this section specifies Eqs. (6) and (7) as final models for quantile estimation as follows:

$$QEPI_{ij}(\tau|X_{ij}) = \alpha_{1,\tau}HDI_{i,\tau} + \alpha_{2,\tau}HDI^2_{i,\tau} + \alpha_{3,\tau}GDPPC_{i,\tau} + \alpha_{4,\tau}GDPPC^2_{i,\tau} + \alpha_{5,\tau}OPN_{i,\tau} + \alpha_{6,\tau}OPN^2_{i,\tau} + \alpha_{7,\tau}URBAN_{i,\tau} + \alpha_{8,\tau}URBAN^2_{i,\tau} + \alpha_{9,\tau}TECH_{i,\tau} + \alpha_{10,\tau}TECH^2_{i,\tau} \quad (6)$$

$$QGDPPC_{ij}(\tau|X_{ij}) = \beta_{1,\tau}EPI_{i,\tau} + \beta_{2,\tau}GCFPC_{i,\tau} + \beta_{3,\tau}LAB_{i,\tau} \quad (7)$$

4. Results and discussion

4.1. Fundamental panel econometric results

Table 4 presents basic panel econometric results. The results show that, except for the EPI model (but significant at 10%), Pesaran's CD result rejects the null hypothesis of no CD at a 1% level of significant. Thus, to confirm the validity of the EPI model, the current study has undertaken further CD tests using Frees. The Frees result is also similar to Pesaran's, implying there is CD in the models. As a result, this study employs Pesaran's (2007) CIPS unit root test. The result strongly fails to accept the null hypothesis of non-stationarity at a 1% significant level at first and second differences.

Similarly, due to the existence of CD and an insufficient number of observations, particularly as the number of variables increases, this study uses the Banerjee and Carrion-i-Silvestre (2017) cointegration tests. Of course, it is possible to use the Westerlund (2007) test for only the growth model, but in the interest of uniformity, this study employs the Banerjee and Carrion-i-Silvestre (2017) tests for both models. The cointegration result fails to accept the null hypothesis of no cointegration at a 1% significant level, implying a long-run relationship among the variables.

4.2. SUR estimation results

The SUR result in Table 5 shows that HDI has a negative and significant effect on EPI. This means a one-unit increase in HDI reduces EPI by 36.932 units. However, the quadratic term of HDI has a positive and significant effect on EPI, which indicates a non-linear association between the variables. Most previous studies decided the relationship (U-shape or inverted U-shape) between the variables based on only the signs of the coefficients. This study uniquely investigates the number of observations below and above the turning point (0.3927 of HDI), findings that over 84% of the observations are above the turning point. This implies that the association between HDI and EPI is dominantly positive. Therefore, the relationship between the variables is positive and non-linear, indicating that most countries are on the rising section of the U-shape. This result implies that healthy and educated societies care about the environment and use advanced technologies that protect the quality of the environment. Regardless of the functional model (linear or non-linear) and the type of proxy variables, the dominantly positive impact of HDI on EPI of this result coincides with Saleem and Shujah-ur-Rahman (2019), Ahmed and Wang (2019), Li and Ouyang (2019), Rahman et al. (2019a), Khan (2020), Kim and Go (2020), Yao et al. (2020), Cakar et al. (2021), and Li and Xu (2021) (see Table 6).

The result also shows that GDPPC significantly reduces EPI. A one-dollar improvement if income level reduces EPI by 0.00095 units. This result coincides with Bernard and Mandal (2016) and Chowdhury and

⁵ 2SLS, 3SLS, MVREG, and GMM.

Table 5. SUR estimation results.

Variables	EPI model		Growth model			
	Coef.	Std. Err.	Coef.	Std. Err.		
HDI	-36.932***	11.23195	-	-		
HDI ²	47.021***	11.77719	-	-		
GDPPC	-0.00094**	0.000397	-	-		
GDPPC ²	1.37e - 07***	3.77e - 08	-	-		
OPN	-0.0293***	0.0106416	-	-		
OPN ²	0.000073*	0.0000434	-	-		
URBAN	-0.096***	0.0355436	-	-		
URBAN ²	0.00152***	0.0003841	-	-		
TECH	10.827***	1.722129	-	-		
TECH ²	-3.051***	0.5182466	-	-		
EPI	-	-	260.475***	9.501829		
GCFPC	-	-	0.267***	0.0282768		
LAB	-	-	-6.791	7.603648		
Constant	37.168***	2.539955	-5944.709***	411.9633		
Other statistics						
	observations	Parms	RMSE	R-sq	Chi2	P
EPI	722	10	3.791413	0.5145	1295.57	0.0000
GDPPC	722	3	1493.665	0.4153	976.35	0.0000

* = significant at the 10% ** = significant at the 5% level *** = significant at the 1% level.

Source: Computed by the author employing Stata 15.

Table 6. 2SLS, 3SLS and MVREG results.

Variables	EPI model					
	2SLS		3SLS		MVREG	
	Coef	Std. Err	Coef.	Std. Err	Coef.	Std. Err
HDI	-47.234***	12.58187	-36.932***	11.23195	-36.91***	11.31851
HDI ²	59.767***	13.1808	47.021***	11.77719	46.99***	11.86794
GDPPC	-0.00237***	0.0004421	-0.00095**	0.000397	-0.00094**	0.0004
GDPPC ²	1.57e - 07***	4.21e - 08	1.37e - 07***	3.77e - 08	1.37e - 07***	3.80e - 08
OPN	-0.0356***	0.0119206	-0.029***	0.0106416	-0.0293***	0.0107236
OPN ²	0.000087*	0.0000486	0.000073*	0.0000434	0.000073*	0.0000437
URBAN	-0.139***	0.0398489	-0.096***	0.0355436	-0.0959***	0.0358175
URBAN ²	0.0021***	0.00043	0.0015***	0.0003841	0.0015***	0.0003871
TECH	16.182***	1.921002	10.827***	1.722129	10.807***	1.7354
TECH ²	-4.657***	0.5781258	-3.051***	0.5182466	-3.045***	0.5222402
CONSTANT	41.342***	2.842602	37.168***	2.539955	37.154***	2.559528
Growth model						
EPI	184.828***	10.07676	260.475***	9.501829	260.037***	9.52826
GCFPC	0.366***	0.0308002	0.267***	0.0282768	0.268***	0.0283555
LAB	-19.594**	8.36865	-6.791	7.603648	-6.8538	7.624798
CONSTANT	-3221.478***	448.5762	-5944.709***	411.9633	-5929.19***	413.1092

* = significant at the 10% ** = significant at the 5% level *** = significant at the 1% level.

Source: Computed by the author employing Stata 15.

Islam (2017). Despite the differences in independent variables and functional models, this result is in line with Akin (2014), Wang et al. (2016), Kais and Sami (2016), Al-Mulali and Ozturk (2016). Munir and Ameer (2018), Rasoulinezhad and Saboori (2018), Khan et al. (2019), Ahmed and Wang (2019), Sultana et al. (2021), and Munir and Ameer (2021). However, the quadratic GDPPC has a positive and significant effect on EPI, implying a non-linear relationship. Regardless of the differences in independent variables and functional models, this result aligns with Al-Mulali and Ozturk (2016). Kais and Sami (2016), Wang et al. (2016), Munir and Ameer (2018), Ahmed and Wang (2019), and Munir and Ameer (2021). 3, 449.64 is the turning point, which implies that up to 3,449.64 of GDPPC, the association between GDPPC and EPI is negative; however, their

relationship turns to positive over this limit. However, their relationship does not follow a U-shape. This is because above 80% of sampled countries' GDPPC stayed below the turning value in most periods, implying a dominantly negative and non-linear relationship between GDPPC and EPI. In other words, since EQ was used in this study instead of pollution, the study's negative and non-linear relationship implies that most nations are located on the traditional EKC's rising section. This implies that economic expansion is linked to poor environmental performance in the initial phase. According to the EKC literature, economic expansion may have three consequences on environmental welfare: scale, composition, and technique. Environmental pollution increases proportionally as the economic scale expands, and pollution intensity decreases as the industrial structure

Table 7. Pearson correlation results.

Variables	EPI model					Growth model				
	EPI	HDI	GDPPC	OPN	URBAN	TECH	GDPPC	EPI	GCFPC	LAB
EPI	1.000						GDPPC	1.000		
HDI	0.624	1.000					EPI	0.5898	1.000	
GDPPC	0.589	0.811	1.000				GCFPC	0.4515	0.218	1.000
OPN	0.092	0.273	0.3206	1.000			LAB	-0.1039	-0.030	-0.071
URBAN	0.428	0.649	0.6533	0.407	1.000					1.000
TECH	0.586	0.735	0.795	0.185	0.534	1.000				
Multicollinearity test										
		VIF		Mean VIF						
GDPPC		4.29		2.78						
HDI		3.37								
TECH		2.96								
URBAN		2.04								
OPN		1.23								

Source: Computed by the author employing Stata 15.

changes. However, African countries' economic activities are not fully transformed into industry and still depend on agricultural activities. Besides, this finding supports the IPAT (STIRPAT) model of the environmental effect of affluence.

Table 5 reveals that international trade negatively and significantly affects EPI. This result is in line with Khalil and Inam (2006), Kleemann and Abdulai (2013), Shahbaz and Leitã (2013), Akin (2014), Li et al. (2016), Rasoulinezhad and Saboori (2018), and Munir and Ameer (2018). The relationship between trade openness and EPI is non-linear, shown by the significant coefficient of the square term of trade openness. Even though the link between trade openness and EPI is negative until 200.673 of trade openness % GDP, it is positive beyond this limit—their association does not follow a U-shape. This is because almost all countries' trade openness in most periods stayed below the threshold value, implying that the association is dominantly non-linear and negative, supports both the pollution haven and race to bottom theories.

According to the pollution haven hypothesis, due to globalisation and trade liberalisation, multinational corporations in more developed economies transfer their poor quality output to developing countries like Africa, where environmental regulations are weak. Similarly, the race to the bottom hypothesis holds due to globalisation and developing countries participating in the global market. Therefore, developing countries like those in Africa open their markets to attract investment, but they may be tempted to relax environmental rules due to worldwide competition. Some economists argue that free trade provides economic growth, which again helps safeguard the environment by increasing the level of income (Sobrinho, 2005). However, in the current study, GDPPC hurts EPI; therefore, trade openness can hurt the environment.

Urbanisation has a negative and significant effect on EPI, which supports the findings of Cole and Neumayer (2004), Dogan and Turkekul (2016), Li et al. (2016), Al-Mulali and Ozturk (2016), Dogan and Turkekul (2016), Kang et al. (2016), Sultane et al. (2021), and Munir and Ameer (2021). Nevertheless, the quadratic term of urbanisation significantly increases EPI, supporting Munir and Ameer's (2021) findings. The link between urbanisation and EPI is negative until 31.446 of urbanisation, yet above this limit, it is favourable. However, in most periods, observations of urbanisation in most countries are beyond the threshold value, implying the relationship is dominantly positive and non-linear, which might be surprising because urbanisation is bad for the environment according to the traditional understanding. This viewpoint has led to constraints on urbanisation in some developing nations. However, urbanisation also provides the rise of the middle class and owners of the property, the expansion of the service sector, a decline in fertility, improved educational attainments, and most importantly, advancement in green technology—all of which help for environmental improvement (Wan and Kahn, 2014).

Table 5 also shows that technology measured in per capita energy consumption positively and significantly affects EPI, which matches with Bernard and Mandal (2016) and Rasoulinezhad and Saboori (2018). Besides, this result supports the pollution halo hypothesis. In other terms, with the introduction of technology, African nations consume relatively low pollution-intensive energies in the long run, promoting EQ. the square term of technology significantly declines EPI. The turning point is around 1.77, which suggests until 1.77 of technology, the association between the variables is positive, but after that point, it is negative. Their relationship does not, however, reflect an inverted U-shape. This is because the majority of the examined countries' technological levels have kept under threshold value, suggesting their relations are primarily positive and non-linear.

The feedback analysis shows that EPI significantly increases GDPPC. Specifically, a one-unit increase in EPI enhances GDPPC by 260.475 USD. Good EQ positively affects economic growth and well-being by improving the quantity and quality of resources or people's health. This result supports the findings of Saboori et al. (2017) in the Chinese case, as well as Li and Xu (2021) and Musibau et al. (2021). Likewise, GCFPC has a positive and significant effect on GDPPC, supporting the findings of Li and Xu (2021). This finding is also consistent with the Solow (1956) and Swan (1956) neoclassical growth model since GCFPC (investment) is considered factors of production. Solow (1956) and Swan (1956) assumed larger investments result in greater capital accumulation per worker, wealth accumulation, the creation of more jobs, and wage increases. This ultimately improves GDPPC (economic growth). Additionally, the endogenous growth model uses a broad definition of capital. As this model noted, physical capital has a positive impact on growth via direct and indirect investment in human capital and domestic and FDI.

4.3. Robustness checks

This study believes that conclusions and policy recommendations obtained solely from the SUR results might not be sufficient without robustness tests. Thus, the study employs 2SLS, 3SLS, and MVREG estimation techniques. Except for the impact of the labour force on GDPPC under 2SLS, all findings are consistent with the SUR results.

4.4. Quantile regression

Table 7 presents the correlation between the variables, and most values are below the rule of thumb (0.7) for a stronger correlation (Allard et al., 2018). However, the correlation between GDPPC and HDI as well as technology and HDI (GDPPC) is above the rule of thumb and is suspected of having a multicollinearity problem. Therefore, this study employs a multicollinearity (VIF) test, which confirms no multicollinearity

Table 8. Quantile estimation results.

Dependent variable EPI						
Variables	Quantiles	Coef. (Std. Err)		Coef. (Std. Err)		Coef. (Std. Err)
HDI	0.2	-55.392*** (19.06751)	OPN	-0.031** (0.014811)	TECH	13.357*** (2.580168)
	0.4	-46.710*** (17.47239)		-0.051*** (0.017306)		11.948*** (2.562608)
	0.5	-47.882** (23.27235)		-0.063*** (0.020050)		11.803*** (3.031809)
	0.6	-60.183** (27.72761)		-0.054** (0.021498)		12.500*** (4.556425)
	0.8	-53.385*** (18.02883)		-0.052** (0.021906)		20.501*** (3.531776)
HDI ²	0.2	76.951*** (21.59606)	OPN ²	9.76E - 05* (5.55E - 05)	TECH ²	-3.567*** (0.703623)
	0.4	69.360*** (18.18413)		0.000140* (7.19E - 05)		-3.346*** (0.759002)
	0.5	69.642*** (22.25564)		0.000160** (8.15E - 05)		-3.442*** (0.856504)
	0.6	75.152*** (26.87989)		0.000111 (9.15E - 05)		-3.786*** (1.287799)
	0.8	59.090*** (19.60482)		8.01E - 05 (0.000134)		-6.268*** (1.010139)
GDPPC	0.2	-0.0025*** (0.000548)	URBAN	-0.171** (0.068666)	CONSTANT	39.040*** (4.464427)
	0.4	-0.0020*** (0.000410)		-0.204*** (0.067988)		40.210*** (3.661849)
	0.5	-0.0022*** (0.000657)		-0.141** (0.064493)		40.970*** (5.431031)
	0.6	-0.0021** (0.000987)		-0.079*** (0.054323)		44.550*** (6.763411)
	0.8	-0.0027*** (0.000801)		-0.0957** (0.042494)		47.148*** (3.999053)
GDPPC ²	0.2	1.79E - 07*** (4.65E - 08)	URBAN ²	0.0023*** (0.000835)		
	0.4	1.51E - 07*** (4.29E - 08)		0.0025*** (0.000637)		
	0.5	1.55E - 07*** (5.81E - 08)		0.0020*** (0.000601)		
	0.6	1.53E - 07** (7.61E - 08)		0.0016*** (0.000538)		
	0.8	1.72E - 07*** (6.19E - 08)		0.0018*** (0.000491)		
Dependent variable GDPPC						
EPI	0.2	46.586*** (7.022452)	LAB	0.2		-27.832*** (2.673761)
	0.4	112.983*** (17.47149)		0.4		-34.404*** (7.204104)
	0.5	106.851*** (19.59799)		0.5		-25.510*** (7.707144)
	0.6	96.868*** (18.42899)		0.6		-19.275*** (6.299288)
	0.8	108.776*** (18.22231)		0.8		1.208 (8.645900)
GCFPC	0.2	0.299*** (0.078432)	CONSTANT	0.2		294.4002 (224.2908)
	0.4	0.500* (0.271380)		0.4		-1089.498*** (257.4615)
	0.5	0.723 (0.454580)		0.5		-1196.907*** (278.5861)
	0.6	1.544*** (0.558849)		0.6		-1190.905*** (342.2443)
	0.8	2.575*** (0.244888)		0.8		-2143.902*** (616.2508)

* = significant at the 10% ** = significant at the 5% level *** = significant at the 1% level. Moreover, the study used a bootstrap of 500 to get the results. Source: Computed by the author employing EViews 15.

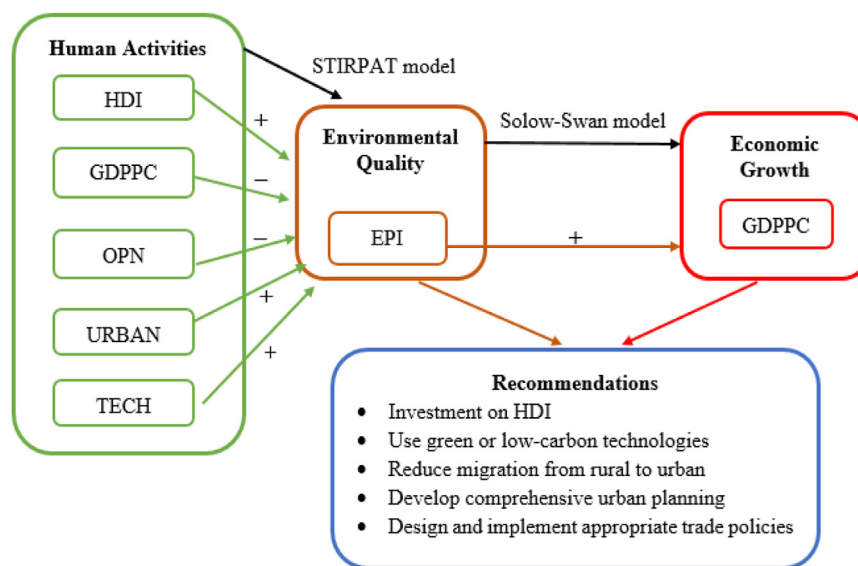


Figure 3. Conclusion and recommendations. Source: Constructed by the author.

in the model. The result shows the VIF values are below 5, with the highest value of 4.29, implying the absence of multicollinearity (see Table 7).

Even though the panel quantile approach does not estimate the models simultaneously, it clearly shows the relationship among the variables and is recommended over panel mean regressions. Therefore, this study utilises panel quantile regressions by choosing five quantiles (20th, 40th, 50th, 60th, and 80th). The panel quantile result in Table 8 fully supports and is consistent with the panel mean results. In other words, the relationship between HDI (technology) and EPI is dominantly positive and non-linear in all quantiles. However, EPI has a negative and non-linear link with GDPPC and urbanisation in all quantiles. Similarly, this study has obtained a negative and non-linear association between trade openness and EPI in most quantiles. In the growth model, EPI significantly increases GDPPC in all quantiles. Likewise, GCFPC significantly increases while labor force significantly reduces the GDPPC of African countries in most quantiles.

Generally, the results of this study have practical and social implications. Since human activities affect the environment's quality, the study has important practical implications for protecting the environment. For instance, studies show that the HDI of Africa is the lowest compared to other continents; hence, countries should adopt human development initiatives that benefit the environment. Moreover, through innovation and technology transfer, countries should implement low-carbon and green technologies. In addition, African countries need to invest directly in low-carbon and efficient technologies. Furthermore, researchers and practitioners can use the results presented in this study for project development.

Environmental degradation causes adverse effects on the socio-economic conditions of African countries. Similarly, this study found that EPI positively affects the economy. Since the economic issues are related to social issues (like health, unemployment, and poverty), protecting the environment is necessary, which in turn improves Africans' social well-being.

5. Conclusion

This study investigates the association between human activities and environmental quality and the environment's effect on African countries' growth from 2000 to 2018. The study employs panel mean SEMs and panel quantile regressions. The study confirms that HDI, technology, and urbanisation have a positive and non-linear relationship with EPI. However, GDPPC and trade openness have a negative and non-linear association with EPI. Further, EPI significantly increases African countries' GDPPC. The study also recommends that African nations prioritise three HDI components (health, education, and activities that promote environmental sustainability). This is because investment in human capital can lead to environmental awareness and less polluting goods in consumption and production processes. In addition, through innovation and technology transfer, countries should implement low-carbon and green technologies to maintain the quality of the environment. Since most of African countries infrastructure, industrial capacity, and the economy are still being constructed, the continent has an opportunity to encourage a low-carbon economy through direct investment in technologies that are efficient and low-carbon.

Although this study is not pessimistic about urbanisation, it does not overlook its cost, such as the rapid migration of people from rural to urban areas. Therefore, African nations should lessen rural to urban migration brought on by social, employment and political problems. Additionally, urban sprawl and unauthorised settlements are widespread in African towns and are usually linked to lesser EQ. Therefore, African nations must establish comprehensive and applicable urban planning. Finally, Africa should develop and implement international trade policies that protect the environment. For instance, African nations should eliminate import restrictions on technologies that protect the environment.

Despite its significant contribution to the literature, this study has some drawbacks. This study employed a conventional neoclassical growth model that considers only a few variables. Besides, this study used total energy consumption instead of decomposed (renewable and non-renewable). Moreover, the study focused on the broad measurement of environmental quality (EPI) rather than its components (EH and EV). Further, this study does not examine categories of EH and EV, though they could potentially reveal in-depth relationships. Furthermore, since balanced data is preferred over unbalanced panels, this study's time scope is limited until 2018 and is unfortunately unable to consider the impact of the COVID-19 outbreak on environmental quality and the economy. Therefore, future research can broaden its scope or further delve into the details by considering these aspects.

Finally, for an easy understanding of the results, this study presents a graphical conclusion and recommendations in Figure 3.

Declarations

Author contribution statement

Sisay Demissew BEYENE, PhD: Conceived and designed the experiments; Performed the experiments; Analyzed and interpreted the data; Contributed reagents, materials, analysis tools or data; Wrote the paper.

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Data availability statement

Data will be made available on request.

Declaration of interest's statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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