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International Journal of Environmental Studies

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/genv20

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To cite this article: Sisay Demissew Beyene & Balázs Kotosz (2020) Testing the environmental Kuznets curve hypothesis: an empirical study for East African countries, International Journal of Environmental Studies, 77:4, 636-654, DOI: 10.1080/00207233.2019.1695445

To link to this article: https://doi.org/10.1080/00207233.2019.1695445

Published online: 28 Nov 2019.

INTERNATIONAL JOURNAL OF ENVIRONMENTAL STUDIES
2020, VOL. 77, NO. 4, 636–654
https://doi.org/10.1080/00207233.2019.1695445

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Testing the environmental Kuznets curve hypothesis: an empirical study for East African countries

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ABSTRACT

The green economy aims to achieve economic growth and development without an adverse effect on the environment. The environmental Kuznets curve (EKC) hypothesis explains the relationship between economic activity and environmental degradation. Using the EKC hypothesis as a theoretical framework, this study tested the EKC hypothesis for 12 East African countries using the Pooled Mean Group (PMG) approach for the period from 1990 to 2013. The result shows that the relationship between per capita income and CO_2 emissions (a proxy for environmental degradation) is bell shaped and thus is an extended version of the original inverted U-shaped curve relationship between economic activities and environmental degradation. Hence, one can conclude that the economic activities in East African countries do not lead to CO_2 emissions. Therefore, environmental conservation policies, technological advancement and modern industrial policies are required to make the economic growth of East African countries effective in reducing CO_2 emissions.

KEYWORDS

GDP per capita; CO_2 emissions; EKC hypothesis; East Africa

Introduction

Although there is general agreement on the meaning of green growth, institutions have defined it in their own ways. For example, the OECD defined green growth as ‘Fostering economic growth and development, while ensuring that natural assets continue to provide the resources and environmental services on which our well-being relies’ [1]. The World Bank defined green growth as ‘Growth that is efficient in its use of natural resources, clean in that it minimises pollution and environmental impacts, and resilient in that it accounts for natural hazards and the role of environmental management and natural capital in preventing physical disasters. And this growth needs to be inclusive’ [2].

The question concerning the significance of nature and the environment for the economy may be found in earlier economic work [3–5]. For example, Ricardo believed that diminishing returns in farm production were caused by the supply of poor-quality land. Malthus argued that, when the population grew with infertile land, the per capita food supply was reduced [3,5–8]. According to Marx, the capitalist system is unsustainable [3,9].

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Published online 28 Nov 2019

The EKC hypothesis has been the dominant theory explaining the link between economic growth and environmental degradation since the early 1990s. The EKC hypothesis argues that there is an inverted U-shaped relationship between economic activity and environmental degradation. Degradation and pollution are high in the early stages of economic growth, but, beyond a certain level of income per capita, the trend reverses, so economic growth leads to environmental improvement at high income levels [10–15].

The carbon dioxide (CO_2) emissions of Sub-Saharan Africa (SSA) fluctuated in magnitude from the early 1990s until the early 2000s. They rose to their maximum level during 2003 but fell in the years 2007 to 2013. Except for 2009, the GDP per capita rose continuously from the early 2000s (see Figures 1 and 2).

Even though the EKC argues that the relationship between economic activity and environmental degradation has an inverted U-shape, there has been empirical evidence to the contrary. Many studies have supported the EKC [16–33], but some have not [34–45]. Further, several studies have found mixed results (supporting the EKC hypothesis for some countries/pollutants but not for other countries/pollutants) [46–55] (see Table 1).

Accordingly, this study examines the relationship between economic growth and CO_2 emissions and the effect of economic growth on the environment in the case of East African countries. There is a lack of empirical studies showing the relationships between economic growth and the environment in the case of East Africa. This necessitates a systematic examination of whether the EKC holds for East African countries. The primary objective of the study is to test the EKC hypothesis for 12[1] of the 22 East African countries.[2]

Literature review

This section concerns the theoretical literature on the economic hypothesis, developed by Kuznets in 1955, the historical background of the EKC hypothesis and its meaning. The theoretical literature has also discussed international agreements on the environment. Meanwhile, in the empirical literature, different studies (differing in the case studies, type of data, methodologies and variables) have supported and opposed the EKC hypothesis.

Theoretical literature

The relationship between development and inequality has been recognised for at least 60 years. Simon Kuznets studied this relationship and produced the Kuznets economic hypothesis. Kuznets [56] argued that, at the initial stage of economic growth, income inequality increases until it reaches a maximum point, and then income variation reduces with economic development. In the early 1990s, the concept of the environmental Kuznets curve (EKC) hypothesis emerged from the work of Grossman and Krueger [10], using the concept of Kuznets [56] as a benchmark. Even though Grossman and Krueger [10] initially examined the impact of North American Free Trade Agreement (NAFTA) on the environment, the starting point for the concept of the EKC was a background study by Shafik and Bandyopadhyay [12] for the World Development Report in 1992. Hence, the EKC argues that 'The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments' and that 'As incomes rise, the demand for

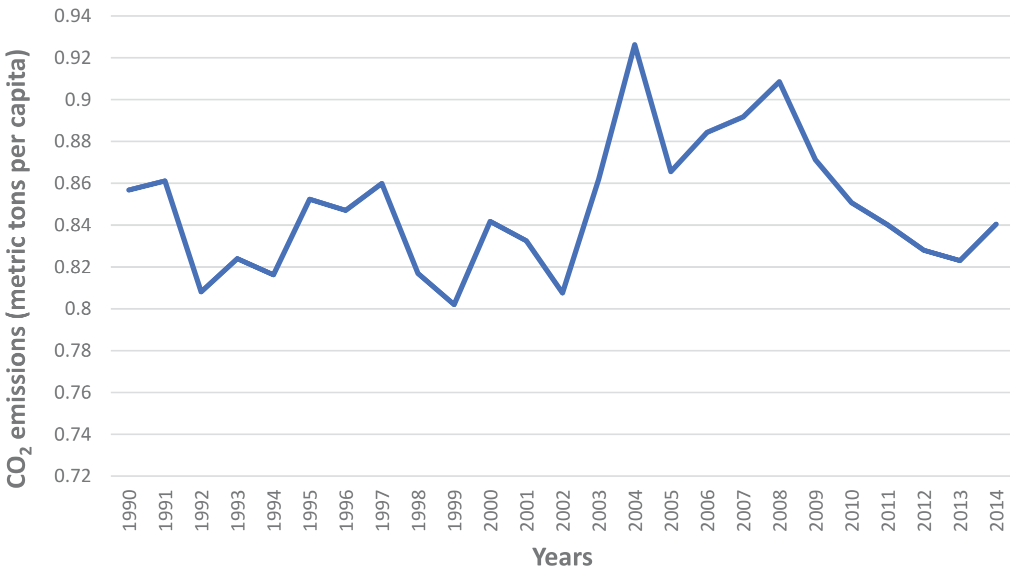

Figure 1. CO_2 emissions of SSA from 1990 to 2014.
Source: Authors' own construction from World Bank data, 2019.

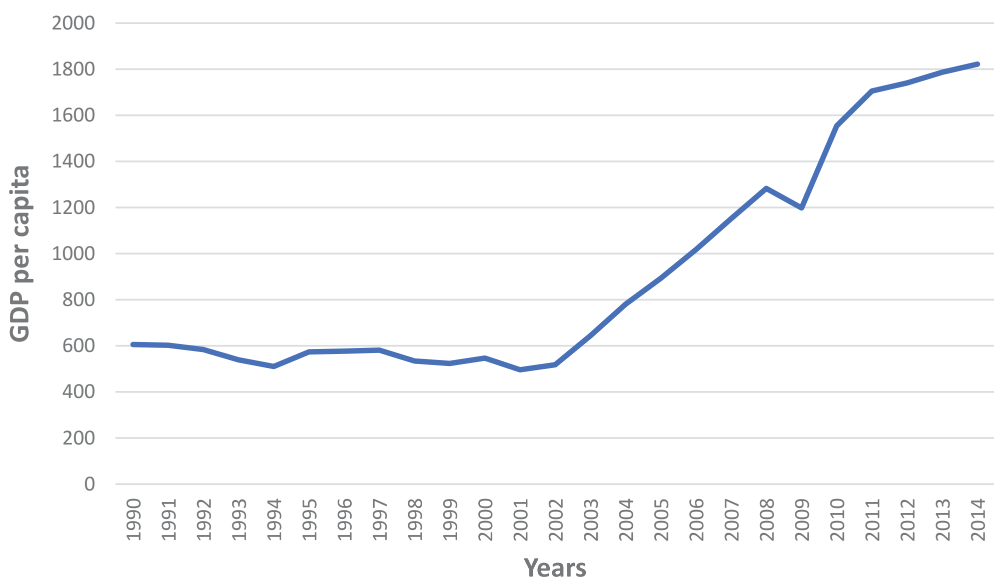

Figure 2. GDP per capita of SSA from 1990 to 2014.
Source: Authors' own construction from World Bank data, 2019.

improvements in environmental quality will increase, as will the resources available for investment'. Further, Beckerman [57] argued that 'there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best and probably the only way to attain a decent environment in

Table 1. Empirical literature.

Author(s)	Model type	Scope of the case study	Results
Grossman and Krueger [16]	GLS	For the years 1977, 1982, 1988 and 1979–1990 for 22 countries	Supports the EKC hypothesis
Ang [17]	Co-integration and vector error correction modelling	From 1960 to 2000, France	Supports the EKC hypothesis
Halicoglu [18]	ARDL and Granger causality test	From 1960 to 2005, Turkey	Supports the EKC hypothesis and bidirectional causality
Jiang et al. [19]	Fixed effects	From 1985 to 2005, China	Supports the EKC hypothesis
Song et al. [20]	Dynamic OLS	From 1985 to 2005, China	Supports the EKC hypothesis
Saboori et al. [21]	ARDL	From 1980 to 2009, Malaysia	Supports the EKC hypothesis
Jobert et al. [22]	Bayesian shrinkage procedure	From 1970 to 2008 for 55 countries	Supports the EKC hypothesis
Shahbaz et al. [23]	ARDL	From 1971 to 2010, Thailand	Supports the EKC hypothesis
Ali et al. [24]	ARDL	From 1972 to 2011, Pakistan	Supports the EKC hypothesis
Ahmed and Qazi [25]	Johansen co-integration	From 1980 to 2010, Mongolia	Supports the EKC hypothesis
Farhani et al. [26]	Panel FMOLS and DOLS estimates	From 1990 to 2010 for 10 Middle East and North African (MENA) countries	Supports the EKC hypothesis
Apergis and Ozturk [27]	GMM	From 1990 to 2011 for 14 Asian countries	Supports the EKC hypothesis
Wolde [28]	VECM	From 1969/70 to 2010/2011, Ethiopia	Supports the EKC hypothesis
Tutulmaz [29]	Johansen and Engle–Granger tests	From 1968 to 2007, Turkey	Supports the EKC hypothesis
Zaied et al. [30]	DOLS estimation method	From 1980 to 2013, Middle East and North Africa (MENA) countries	Supports the EKC hypothesis
Barra and Zotti [31]	GMM	From 2000 to 2009 for 120 countries	Supports the EKC hypothesis
Armeanu [32]	Pooled OLS and fixed effects	From 1990 to 2014 for 28 EU countries	The pooled OLS supports the EKC hypothesis for emissions of sulphur oxides and non-methane volatile organic compounds; besides, the fixed-effect estimate validates the EKC hypothesis for many types of pollutants
Shahbaz et al. [33]	ARDL	From 1980 to 2010, Romania	Supports the EKC hypothesis
Friedl and Getsner [34]	OLS	From 1960 to 1999, Austria	Does not support the EKC hypothesis
Cialani [35]	OLS	From 1861 to 2002, Italy	Does not support the EKC hypothesis
Soytas et al. [36]	Toda–Yamamoto procedure	From 1960 to 2004, United States	Does not support the EKC hypothesis
Asghari [37]	2SLS	From 1980 to 2011, Iran	Does not support the EKC hypothesis
Inglesi-Lotz and Bohlmann [38]	ARDL	From 1960 to 2010, South Africa	Does not support the EKC hypothesis
Al-Mulali et al. [39]	ARDL	From 1981 to 2011, Vietnam	Does not support the EKC hypothesis
Jebli and Youssef [40]	VECM	From 1980 to 2009, Tunisia	Does not support the EKC hypothesis

(*Continued*)

Table 1. (Continued).

Author(s)	Model type	Scope of the case study	Results
Adu and Denkyirah [41]	The fixed- and the random-effect model	From 1970 to 2013, West African countries	Does not support the EKC hypothesis
Monserrate et al. [42]	ARDL and Granger causality test	From 1980 to 2011, Peru	Does not support the EKC hypothesis
Al Sayed and Sek [43]	Fixed effects and random effects	From 1961 to 2009 for 40 DC and LDCs	The EKC does not hold in all countries
Lantz and Feng [44]	Pooled and fixed effects	From 1970 to 2000 for five regions in Canada	Does not support the EKC hypothesis
Akpan and Akpan [45]	VECM	From 1970 to 2008, Nigeria	Does not support the EKC hypothesis
Grossman and Krueger [46]	Random effects	For the years 1977, 1982 and 1988 for 42 countries	Supports the EKC hypothesis in the case of suspended particulate matter (SPM) and dark matter (smoke) but not for sulphur dioxide (SO_2)
Selden and Song [47]	Fixed and country-specific effects	From 1951 to 1986 for 130 countries	Mixed results depending on the model form
Cole et al. [48]	GLS (and OLS)	From 1970 to 1992 for OECD countries	Among different pollution indicators (nitrogen dioxide (NO_2), SO_2, SPM, carbon monoxide (CO) and ammonium cation (NH4) municipal waste, chlorofluorocarbons), the study supports the EKC hypothesis only for local air pollutants
Shafik [49]	OLS	From 1960 to 1990 for 149 countries	Supports the EKC hypothesis for the case of SO_2 and the SPM pollutants but not for carbon emissions per capita and deforestation
Hung and Shaw [50]	2SLS	From 1988 to 1997, Taiwan	Mixed results – supports the EKC hypothesis for NO_2 and CO but not for SO_2
Shaw et al. [51]	Time-specific fixed-effects panel models	From 1992 to 2004, China	Mixed results – supports the EKC hypothesis for SO_2 but not for deposited particles and NOx
Cetin [52]	PMG	From 1990 to 2011, emerging and developed markets	The EKC hypothesis is not confirmed for emerging markets; however, it is supported for developed markets
Sica [53]	Fixed and random effects	From 1990 to 2011, Italy	Supports the EKC hypothesis for CO_2 and NOx but not for SOx
Taguch [54]	GMM	From 1950 to 2009, for 19 Asian countries	Supports the EKC hypothesis for sulphur emissions, while CO_2 tends to expand in line with per capita income
Roca et al. [55]	OLS Estimation	From 1972–1996 for carbon dioxide, from 1980–1996 for other pollutants, Spain.	Among different pollution indicators, the study supports the EKC hypothesis only for SO_2 (not for CO_2).

Source: Constructed by the authors, 2019.

most countries is to become rich'. Adopting the concept of the EKC hypothesis, Grossman and Krueger [10] and Grossman and Krueger [46] validated the relationship between per capita income and environmental degradation as having an inverted U-shape (see Figure 3).

Figure 3 shows the inverse U-shaped graphical representation of the hypothesis. The dependent variable is environmental degradation, which is proxied by any pollutants (air, water and land or soil pollution) or deforestation. The dependent variable is per capita income.

The relationship between economic activities and environmental degradation is not only direct but can also be indirect through trade. According to Sobrinho [59], some economists believe that free trade brings economic growth and that economic growth, in turn, helps to protect the environment from damage through raised incomes. Conversely, others think that free trade increases environmental damage by raising consumption and production, thereby exerting increasing pressure on natural resources. It appears, however, that not only does the level of economic growth have an impact on environmental pollution but also pollution can have an impact on growth and the level of development. Mirza and Kanwal [60] and Armeanu et al. [32] argued that there are two different views on the connection between energy consumption and economic growth. Regarding the neo-classical (neutrality) hypothesis, Menegaki [61] believed that there is no relation between energy consumption and economic growth owing to the presence of other essential inputs for growth than energy [32]. But, the non-neutrality hypothesis argues that, since energy is an essential factor of production, environmental conservation policies can reduce economic growth. Further, Tugcu et al. [62] contended that there are three theoretical models under the non-neutrality hypothesis: (1) the growth hypothesis, which supports unidirectional causality

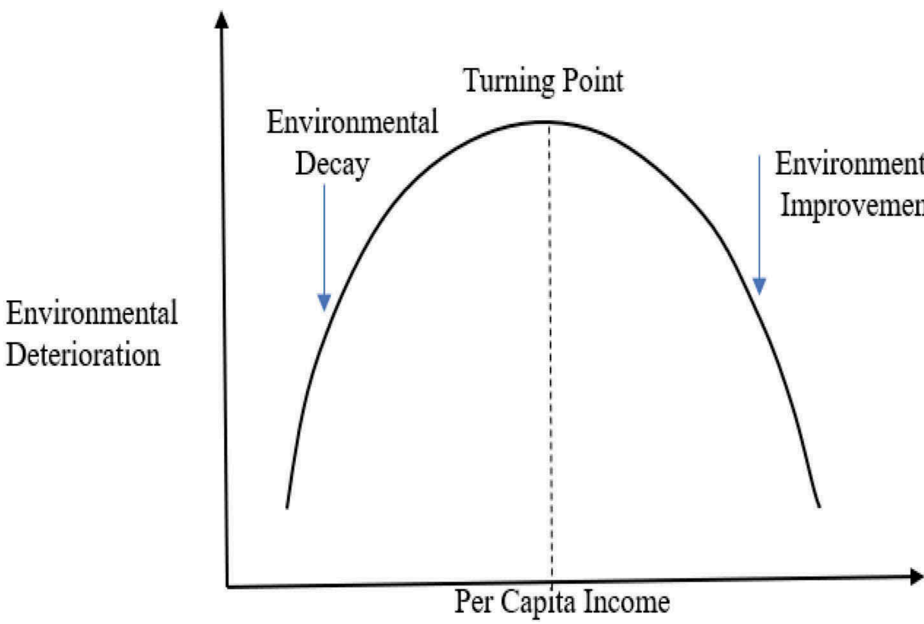

Figure 3. A typical EKC diagram.
Source: Yandle et al. [58], p. 3.

from energy consumption to economic growth [63]; (2) the conservation hypothesis, which advocates unidirectional causality from economic growth to energy consumption [64]; and (3) the feedback hypothesis, which postulates bidirectional causality between energy consumption and economic growth [65].

Hence, in addition to the conservation hypothesis, many studies have been conducted based on the growth and feedback hypotheses. For example, the growth hypothesis was supported by Dinda and Coondoo [66] for European countries, Cowan et al. [67] for Brazil and Omri et al. [68] for Europe and Central Asia, Latin America and the Caribbean countries. Mirza and Kanwal [60], Chaabouni et al. [69] and Shahbaz et al. [33] supported the feedback hypothesis.

Nevertheless, because of the bidirectional relationship between economic growth and development and environmental pollution, the endogeneity problem can arise. Hence, simple OLS, as well as the VAR framework, leads to spurious results. This study used PMG estimation techniques to overcome these limitations.

History of environmental agreements

The first international agreement on the climate issue was adopted by the United Nations Framework Convention on Climate Change (UNFCCC) in 1992. It aims to stabilise the greenhouse gas concentrations in the atmosphere. According to the UNFCCC, countries have different responsibilities: developed countries are more responsible for greenhouse emissions and hence they have to fight against climate change by reducing their pollution as well as providing support (including financial support) to developing countries [70].

The second agreement was the Kyoto protocol of 1997. It forces developed countries to reduce their greenhouse gas emissions that contribute to global warming to 5 per cent below the 1990 levels by 2012. Besides, to meet developed countries' commitment to emission reduction projects in developing countries, the Kyoto protocol develops an international emissions-trading system and a clean development mechanism (CDM). It is not as effective as expected because of the US's unwillingness to ratify the protocol [70,71].

Following the Kyoto protocol, the Copenhagen agreement was established in 2009. It is a non-binding document that sets a target of limiting the global temperature rise to 2 degrees, establishes the Green Climate Fund and agrees a goal to provide climate finance from 'a wide variety of sources', worth US$100 billion per year, to developing countries by 2020. Countries have made voluntary mitigation pledges for the period up to 2020 [70].

Other initiatives include the Conference of the Parties (COP) 17 of 2011, the announcement of China and the US about addressing climate change in 2014, the LIMA conference in 2014, and COP 21 in October 2015. The main agreement (Paris Agreement) was reached on 12 December 2015. It has a new legally binding framework for an internationally coordinated effort to tackle climate change; it establishes a global warming goal of well below 2°C of the pre-industrial average [70].

Empirical literature

This section presents the empirical literature about the environmental Kuznets curve. Table 1 shows the authors' names along with the year, their model, the time scope of their case studies and their findings. All have endeavoured to explain the EKC hypothesis with various methodologies, data and cases.

Table 1 shows that different studies obtained different results owing to their selection of pollution indicators (CO_2, SO_2, NO, SPM, etc.), estimation techniques, independent variables included in the model, time scope and case studies. Most studies supported the EKC hypothesis.

Data sources, model specification and methodology of the study

This section presents the data type, sources and data analysis of the study. Besides, using the theoretical and empirical studies as a benchmark, it specifies the model. Furthermore, the methodology and estimation techniques are described in detail.

Data type, source and data analysis

This study used time series data running from 1990 to 2013. The sources of the data were the WB, KOF Swiss Economic Institute and Polity IV databases (see Table 2). Since data are lacking, this study could examine only 12 of the 22 East African countries.

Model specification, estimation technique and procedures

To test the EKC hypothesis in the case of East African countries, this study used the theoretical and empirical findings to develop the following model:

$$\begin{aligned}\mathrm{LN}CO_{2\mathrm{it}} = {} & \beta_0 + \beta_1\mathrm{LNGDPPC_{it}} + \beta_2\mathrm{LNGDPPC2_{it}} + \beta_3\mathrm{LNGLOB_{it}} + \beta_4 LNFDI_{it} \\ & + \beta_5 LNPOPD_{it} + \beta_6 POLITY2_{it} + \varepsilon_{\mathrm{it}}\end{aligned} \tag{1}$$

where $\mathrm{LNCO_2}$ is the natural logarithm of carbon dioxide emissions and LNGDPPC and LNGDPPC2 (our target variables) represent the natural logarithm of the GDP per capita and its square, respectively. LNGLOB and LNFDI are the natural logarithms of globalisation and foreign direct investment, respectively. Further, to incorporate the political condition of the country, we added POLITY2, and ε_{it} is the error term. The parameters$(-)\beta_1, (-)\beta_2, (-/+)\beta_3, (-/+)\beta_4, (+)\beta_5\ and\ (-)\beta_6$ are the coefficients of LNGDPPC, LNGDPPC2, LNGLOB, LNFDI, LNPOPD and LNPOLITY2, respectively.

Table 2. Variables in the model: measurements and data sources.

Variable	Definition and measurement	Data sources
$\mathrm{LNCO_2}$	Natural logarithm of CO_2 emissions measured as metric tons per capita	WB database
LNGDPPC	Natural logarithm of GDP per capita measured in US$	WB database
LNGDPPC2	Square of the natural logarithm of GDP per capita measured in US$	WB database
LNGLOB	Natural logarithm of globalisation measured as an index	KOF Swiss Economic Institute
LNFDI	Natural logarithm of foreign direct investment measured in US$	WB database
LNPOPD	Natural logarithm of population density measured as people per sq. km of land area	WB database
POLITY2	Political stability measured as the country's elections competitiveness and openness, the nature of political involvement in general and the degree of checks on administrative authority. The estimate gives the country's score on the aggregate indicator in units of a standard normal distribution, ranging from −10 to +10.	Polity 2 data series from the Polity IV database

Source: Constructed by the authors, 2019.

Besides, the signs in the parentheses in front of the coefficients are the expected hypothesised signs of the variables.

In this study, we used Pesaran et al.'s [72] PMG estimation approach, which assumes that the parameters are heterogeneous across groups. The PMG estimator combines pooling and averaging of coefficients. Pesaran et al. [72] considered that the analysed economies differ in their economic policy. To them, the PMG was significant relative to other panel data models, because it allows the short-run responses to be flexible and unrestricted across groups while imposing restrictions by pooling individual groups in the long run. In other words, the likelihood-based PMG estimator constrains the long-run elasticity to be equal across all panels, yielding efficient and consistent estimates only when the homogeneity restriction is indeed real. Furthermore, when the number of observations is small, the PMG estimator is less sensitive to outliers and can simultaneously correct the serial autocorrelation problem and the problem of endogenous regressors by choosing an appropriate lag structure for both dependent and independent variables [72].

In time series analysis, testing the stationarity of the variables is vital to avoid spurious results. Hence, we performed the tests by Levin et al. [73] and Im et al. [74] and the Fisher-type ADF test. Besides, testing the co-integration of the variables to determine the long-run relationship among the variables is essential. If there is a long-run relationship among the variables, our estimated model appears as follows:

$$\begin{aligned} LNCO_{2it} = {} & \alpha_i + \sum_{j=1}^{P} \lambda_{ij} LNCO_{2i,t-j} + \sum_{j=0}^{q} \delta'_{1ij} \mathrm{LNGDPPC}_{i,t-j} + \sum_{j=0}^{q} \delta'_{2ij} \mathrm{LNGDPPC2}_{i,t-j} \\ & + \sum_{j=0}^{q} \delta'_{3ij} \mathrm{LNGLOB}_{i,t-j} + + \sum_{j=0}^{q} \delta'_{4ij} LNFDI_{i,t-j} + \sum_{j=0}^{q} \delta'_{5ij} \mathrm{LNPOPD}_{i,t-j} \\ & + \sum_{j=0}^{q} \delta'_{6ij} \mathrm{POLITY2}_{i,t-j} + \varepsilon_{it} \end{aligned} \tag{2}$$

The re-parameterised form of Equation (2) can be formulated as follows:

$$\begin{aligned} \Delta LNCO_{2it} = {} & \alpha_i + \varphi_i LNCO_{2i,t-1} + \beta'_{1i} \mathrm{LNGDPPC}_{it} + \beta'_{2i} \mathrm{LNGDPPC2}_{it} + \beta'_{3i} \mathrm{LNGLOB}_{it} \\ & + \beta'_{4i} \mathrm{LNFDI}_{it} + \beta'_{5i} \mathrm{LNPOPD}_{it} + \beta'_{6i} \mathrm{POLITY2}_{it} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta \mathrm{LNCO2}_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta'_{1ij} \Delta \mathrm{LNGDPPC}_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{2ij} \Delta \mathrm{LNGDPPC2}_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{3ij} \Delta \mathrm{LNGLOB}_{i,t-j} + \\ & + \sum_{j=0}^{q-1} \delta'_{4ij} \Delta \mathrm{LNFDI}_{i,t-j} + \sum_{j=0}^{q-1} \delta'_{5ij} \Delta \mathrm{LNPOPD}_{i,t-j} \\ & + \sum_{j=0}^{q-1} \delta'_{6ij} \Delta \mathrm{POLITY2}_{i,t-j} + \varepsilon_{it} \end{aligned} \tag{3}$$

Results and discussion

This section presents the econometric results and their interpretation along with the theoretical and empirical support of the study: i.e., the descriptive statistics, the unit root test using the LLC, IPS and Fisher ADF methods, the co-integration test using the Padroni residual test and the long-run and short-run dynamics results.

Descriptive statistics of the variables

Table 3 shows the descriptive statistics of the variables relating to the 12 East African countries. The mean of $LNCO_2$ emissions is −2.07, and the range is between −3.875 and 1.17, showing that the variation is not large. Similarly, the mean values of our target variables (LNGDPPC and LNGDPPC2) have a small variation in their range. For example, the mean values of LNRGDPPC and LNGDPPC2 are 6.34 and 41, respectively. Further, the value of the range of LNGDPPC is between 5 and 9, and the range of LNGDPPC2 is between 25.87 and 82.59. Generally, the ranges of our dependent and independent variables show low variation; the descriptive statistics of the other variables appear in Table 3.

Table 3 reveals that all the variables are positively skewed except the natural logarithm of FDI. In addition, all the variables have positive kurtosis with a value below 6. The deviation of the variables from their means, as shown by the standard deviation, indicates a small growth rate (fluctuation) of these variables over the study period.

Unit root and co-integration tests

Before we checked the presence of a long-run relationship (co-integration) between the variables, we determined the order of integration of each variable in the model by using three commonly used panel unit root tests: the tests by Levin et al. [73] and Im et al. [74] and the Fisher-ADF test. The unit root test shows that all the variables included in the model are I(1) (see Annexe 1).

Following the unit root test, this study used the Pedroni [75] residual co-integration test to confirm the existence of a long-run relationship among the variables. The advantages of the Pedroni residual-based test relative to others (Kao and Fisher) are that it accounts for heterogeneity by using specific parameters and it assumes cross-sectional dependence. In the Pedroni test, there are 11 panel statistics for which co-integration analysis can be performed. Hence, in our model, with an intercept only, the null hypothesis of no co-integration is rejected at the 1 per cent level of significance for 6 out of the 11 test statistics (see Table 4).

The long-run estimation results

Table 5 shows the results of the long-run relationship between the CO_2 emissions and the independent variables. Our target variables, GDP per capita and its square, are negatively and positively significant in affecting the CO_2 emissions, respectively. Unlike our expectation of the existence of an inverted U-shaped relation between economic growth and CO_2 emissions, our study shows the U-shaped relationship. Hence, it does not support the existence of the EKC (inverted U-shape). This means that, up to 128.95 of GDPPC,

Table 3. Descriptive statistics of the variables.

	$LNCO_2$	LNGDPPC	LNGDPPC2	LNGLOB	LNFDI	LNPOPD	POLITY2
Mean	−2.07	6.34	40.99	3.66	17.26	4.53	1.20
Median	−2.37	6.12	37.47	3.69	17.88	4.51	0.000
Max.	1.17	9.08	82.59	4.24	22.62	6.42	10.00
Min.	−3.875	5.086	25.87	3.11	4.4	2.38	−9.00
Std Dev.	1.067	0.87	12.14	0.24	3.24	1.144	5.618
Skewness	1.449	1.38	1.75	0.001	−1.29	0.000	0.05
Kurtosis	5.09	4.89	5.95	2.48	5.24	1.78	1.67
Prob.	0.000	0.0000	0.0000	0.202	0.000	0.000	0.000

Observations N = 288
n = 12
T = 24
N, n and T in the table represent the total observations, the total number of countries sampled and the total number of years for the study, respectively.
Source: Computed by the authors using Eviews 9.

Table 4. Pedroni co-integration test.

		Statistic	Prob.	Weighted statistic	Prob.
Within-dimension	Panel v-statistic	−0.77	0.779	−3.01	0.998
	Panel rho statistic	2.11	0.98	2.01	0.977
	Panel PP statistic	−2.5	0.0061***	−4.011	0.0000***
	Panel ADF statistic	−2.81	0.0025***	−4.42	0.0000***
Between-dimension	Group rho statistic	2.879	0.998	-	-
	Group PP statistic	−4.588	0.0000a	-	-
	Group ADF statistic	−3.5	0.0002a	-	-

*** Significant at the 1 per cent level.
Source: Computed by the authors using Eviews 9.

the relationship between GDP per capita and CO_2 emissions is negative; over this limit, it is positive. Besides, even though the minimum value is 128.95, the GDPPC values of all the countries are above the minimum value. This indicates that the relationship between economic growth and CO_2 emissions has the bell shape rather than the inverted U-shape of the Kuznets hypothesis (see Annexe 2). Similar to our result, other studies have also not supported the EKC hypothesis [34–45].

There are different carbon reduction projects in Africa, like the clean development mechanism (CDM) of the Kyoto protocol. For each ton of CO_2 reduced that the Kyoto protocol targeted, the CDM projects can earn commercial certified emission reduction (CER) credits. Further, to help those countries meet their emission reduction requirements, the CERs can be sold on one of several international carbon exchanges. Only 25 out of a total 1078 registered CDM projects are in Africa. There are 13 in South Africa, 4 in Morocco, 3 in Egypt, 2 in Tunisia, and 1 in each of Uganda, Nigeria and Tanzania [76]. This indicates that only 2 East African countries are benefiting from CDM projects. If this condition continues, in the long run, it will be difficult to reduce the carbon dioxide emissions in East Africa. Hence, to reduce the carbon emissions further (like our short-run result) and to support the EKC hypothesis in East Africa, such projects should be encouraged by making the political, social and legal environment attractive.

Moreover, funds (assistance) for environmental protection have their own role in reducing the carbon dioxide emissions. Africa is receiving some assistance through two funds operated by the Global Environment Facility (GEF). The least developed countries

Table 5. Estimated long-run coefficients using the PMG approach.

Variables	Coefficients	Std error	Z-statistic	Prob.
LNGDPPC	−2.986	1.622	−1.84	0.066*
LNGDPPC2	0.307	0.132	2.32	0.020**
LNGLOB	1.061	0.347	3.05	0.002***
LNFDI	−0.011	0.010	−1.14	0.255
LNPOPD	0.435	0.345	1.26	0.208
POLITY2	−0.050	0.005	−9.60	0.000***

*Significant at the 10 per cent level, ** significant at the 5 per cent level, *** significant at the 1 per cent level.
Source: Computed by the authors using Stata 14.

Table 6. Estimated short-run coefficients using the PMG approach.

Variables	Coefficients	Std error	Z-statistic	Prob.
ECM	−0.364	0.089	−4.07	0.000***
D(LNGDPPC)	33.742	13.792	2.45	0.014**
D(LNGDPPC2)	−2.588	1.081	−2.39	0.017**
D(LNGLOB)	−0.138	0.212	−0.65	0.514
D(LNFDI)	0.0009	0.009	−0.10	0.920
D(LNPOPD)	−12.423	8.599	−1.44	0.149
D(POLITY2)	0.017	0.001	1.72	0.082*
CONSTANT	−0.097	0.213	−0.45	0.649

*Significant at the 10 per cent level, **significant at the 5 per cent level, ***significant at the 1 per cent level.
Source: Computed by the authors using Stata 14.

fund has attracted about $116 million in promises since 2001. Among the East African countries, Ethiopia (to strengthen the ability of pastoralists and farmers to cope with drought) and Kenya (to build national, provincial and community capacity, to understand and manage climate change and to encourage private sector participation in climate change adaptation) have received special funding. But the grants are too small to have a dramatic impact on the environment. Therefore, in the long run, the grants may not be effective in reducing carbon dioxide. Hence, increasing the funds for East African countries is essential for environmental protection, and the results obtained through the steps may prove the hypothesis (like our short-run result).

The short-run estimation results

Unlike the long-run results, in the short run, our target variables (the first difference of GDP per capita and its square) affect the CO_2 emissions positively and negatively, respectively. In the short run, up to 677.35 of GDPPC, the relationship between the GDP per capita and the CO_2 emissions is positive, but it is negative afterwards. This indicates that the relationship between economic growth and CO_2 emissions has an inverted U-shape in the short run (see Table 6).

The World Bank Group supports some projects in East Africa that lower greenhouse gas emissions and earn carbon credits. Humbo assisted the natural regeneration project of Ethiopia, which helped to restore 2,700 hectares of land. The Olkaria II Unit 3 geothermal expansion project in Kenya helped to add 35 megawatts of electricity to the Kenyan national grid and issued over 230,000 carbon credits. Madagascar has the Ankeniheny-Zahamena Corridor Biodiversity Conservation (REDD+) project, which generated almost 4 million carbon credits and has provided other benefits for the community (fish farming, improved irrigated rice cultivation and bean production). Rwanda's Electrogaz Compact Fluorescent Lightbulb Distribution project distributed 800,000 compact fluorescent lamps in the last 8 years, reducing the equivalent of 21,000 tons of carbon dioxide per year, and has generated 130,000 carbon credits [77]. Hence, in the short run, the above projects have contributed to the reduction of greenhouse gas emissions in general and carbon dioxide emissions in particular in East African countries. From this, one can understand that the short-run results can be a base for the long-run results, so promoting these types of projects is important for reducing the carbon dioxide emissions in the long run as well.

Further, subject to the developed countries' support (financial, technological and capacity building), the climate change policy of the East African Community (EAC) states that East African nations have a role to play in mitigation in the forestry, energy, industry, transport, waste management and agricultural sectors. The objective of the policy is to 'increase availability and access to sustainable, reliable and affordable renewable energy sources'. Each member has an obligation: to scale up the investment in renewable energy technologies to offer access to cheap, cleaner energy as well as improving efficiency in the use of biomass energy; to develop suitable alternative energy sources, policies and measures to enhance energy efficiency; to create a good approach to the development of biofuels for mitigation and energy in view of food security issues; and to improve energy efficiency and promote clean energy technologies, including hydropower, solar and wind [78]. Therefore, in the short run, the climate change policies of the EAC contribute to reducing the carbon dioxide emissions of our case studies. This is because, in the short run, most policies require monitoring and evaluation, and most countries can follow the policies. But, in the long run, the monitoring and evaluations will be weak. What we can learn from this short-run result is that policies should be applicable and effective, along with their monitoring and evaluation, both in the long run and in the short run.

Finally, it is possible to develop different laws to ensure the reduction of carbon emissions. The carbon tax legislation of South Africa and the carbon footprint of Tanzania are the primary legislation for East African countries to adopt as well. Besides, the forest-related legislation to support the reduction of emissions from deforestation and forest degradation of Cameroon, Kenya, Nigeria and South Africa can be a model for East African countries.

The coefficient of the error correction term lagged by 1 period (ECM) is negative (between 0 and −1) and highly significant at the 1 per cent level of significance. This confirms the existence of the co-integration relationship among the variables in the model. It stands for the rate of adjustment to restore equilibrium in the dynamic model following a disturbance. The coefficient of the error correction term is −0.364. This means that the deviation from the long term is corrected by approximately 36 per cent each year owing to variations from the short run towards the long run. In other words, the significant error correction term suggests that around 36 per cent of the disequilibrium in the previous year is corrected in the current year.

Conclusion

Achieving rapid and sustainable economic growth without an adverse effect on the natural environment is a current concern for researchers, academics and policy makers. The well-known theory that explains the relationship between economic activity and environmental degradation is the EKC hypothesis. Hence, the primary objective of this study was to test the EKC hypothesis in the case of 12 East African countries for the time period from 1990 to 2013 using the PMG estimation technique. Accordingly, in addition to the GDP per capita, square of the GDP per capita, globalisation, foreign direct investment and population density, political variables were added to the model to determine their effect on the CO_2 emissions in East African countries. The study confirmed that, in the long run, the relationship between economic growth and CO_2 emissions is not as Kuznets assumed (an inverted U-shape); instead, it has a bell shape. This means that the relationship between the GDP per capita and the CO_2 emissions is negative until the GDP per capita reaches 128.95 USD (the turning point), but it is positive after that point. But, the reverse (an inverted U-shape) occurs in the short run. This means that the turning point is about US$ 677.35 of GDP per capita in the short run. Hence, in the long run, deliberate policies like environmental conservation policies, the adoption of new technologies that reduce pollution and the modernisation of the existing industries, are required to make the economic growth of East African countries effective in reducing CO_2 emissions in the long run.

Notes

1. Burundi, Comoros, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mozambique, Rwanda, Sudan, Tanzania and Uganda.
2. The East African countries are Burundi, Comoros, Djibouti, Egypt, Eritrea, Ethiopia, Kenya, Madagascar, Malawi, Mauritius, Mayotte, Mozambique, Reunion, Rwanda, Seychelles, Somalia, South Sudan, Sudan, Tanzania, Uganda, Zambia and Zimbabwe [79].

Acknowledgements

This research was supported by the project nr. EFOP-3.6.2-16- 2017-00007, titled Aspects on the development of intelligent, sustainable and inclusive society: social, technological, innovation networks in employment and digital economy. The project has been supported by the European Union, co-financed by the European Social Fund and the budget of Hungary. The contents of the paper are the sole responsibility of the authors and can under no circumstances be regarded as reflecting the position of the European Union.

Disclosure statement

No potential conflict of interest was reported by the authors.

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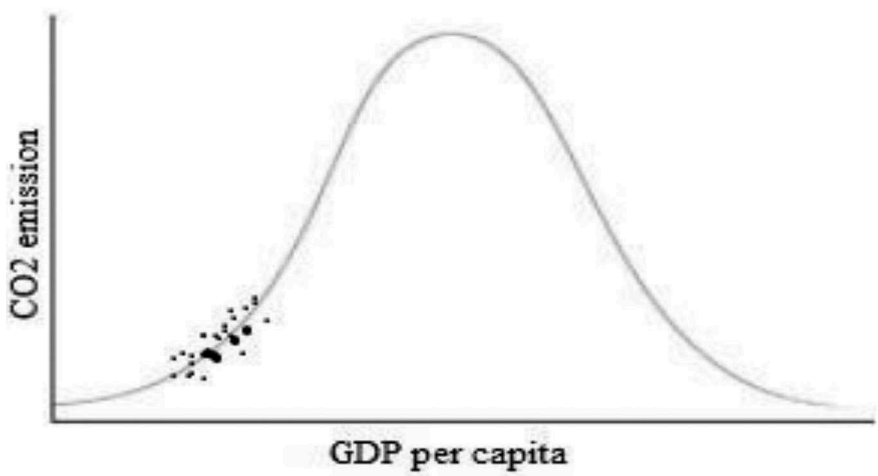
Annexes

Annexe 1. Panel unit root test

Variables	Statistics	Values	Order of integration
$LNCO_2$	LLC	−12.73***	I(1)
	IPS	-11.45***	I(1)
	ADF	153.98***	I(1)
LNGDPPC	LLC	−11.80***	I(1)
	IPS	-11.56***	I(1)
	ADF	157.71***	I(1)
LNGDPPC2	LLC	−12.10***	I(1)
	IPS	-11.59***	I(1)
	ADF	157.5***	I(1)
LNGLOB	LLC	−11.33***	I(1)
	IPS	-11.43***	I(1)
	ADF	155.83***	I(1)
LNFDI	LLC	−12.07***	I(1)
	IPS	-13.52***	I(1)
	ADF	276.26***	I(1)
LNPOPD	LLC	−4.66***	I(1)
	IPS	-8.63***	I(1)
	ADF	308.57***	I(1)
POLITY2	LLC	−8.437***	I(1)
	IPS	-7.30***	I(1)
	ADF	78.94***	I(1)

***significant at the 1 per cent level.
Source: Computed by the authors using Eviews 9.



Annexe 2. The suggested EKC diagram

Source: Authors' own construction.