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REVISITING ENVIRONMENTAL KUZNETS CURVE AND THE ROLE OF ENERGY CONSUMPTION: THE CASE FOR NAMIBIA

Tafirenyika Sunde

Abstract

The study aims to investigate the dynamic relationship between CO_2 emissions, economic growth, and energy consumption for the period 1991:q1-2016:q4 in the case of Namibia. The study applies the ARDL and Granger causality analysis to investigate the long run and causal relationships among these variables, respectively. The study confirms the long run relationship between CO_2 emissions, economic growth, and energy consumption. The results show that the Environmental Kuznets Curve (EKC) is found in both long and short runs in Namibia and that all the variables Granger cause each other. These results imply that economic growth can be a remedy for environmental degradation which means that the exploitation of natural resources to realise economic growth can be accepted until the turning point of the EKC curve is reached. The study recommends that actions to slow down the release of CO_2 emissions and the raising of awareness about environmental concerns should wait until the economy reaches high-income levels.

Keywords: Environmental Kuznets Curve; CO_2 emissions; economic growth; energy consumption; ARDL-ECM; Granger causality; Namibia.

1. Introduction

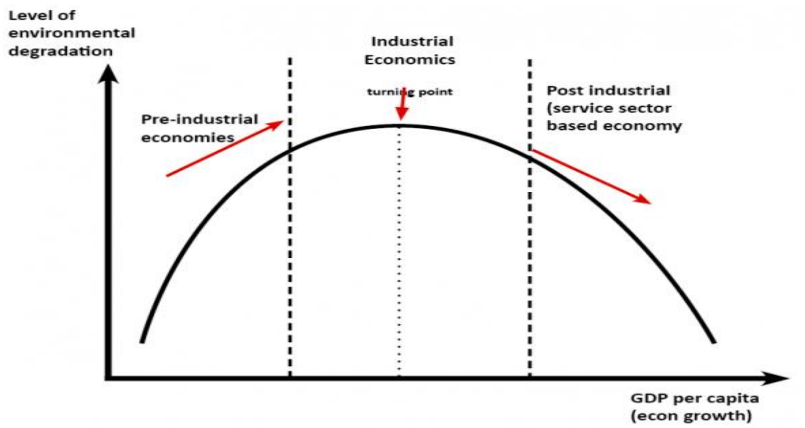
Emissions of CO_2 from fuel combustion have more than tripled between 1960 and 2014, and their sources have changed over time (Magazzino, 2015, 2016). It should be noted that CO_2 emissions are the most significant source of concern with regards to global warming, and CO_2-energy consumption-GDP models are likely to have a significant part in assisting the understanding of how population and the relationship between economic growth and energy consumption are likely to influence future CO_2 emissions. According to Panayotou (1997) and Magazzino (2014), faster economic growth and more concentrated population density beyond a certain point are likely to increase the environmental costs of economic growth moderately.

He and Richard (2010) observed that there seems to be principally three strands in the literature on the relationship between economic growth and environmental pollutants. The first strand concentrates on the economic growth and environmental pollutants nexus which tests the validity of the environmental Kuznets curve (EKC) (Kuznets, 1955). Theoretically, the EKC hypothesis postulates the existence of an inverted U-shaped relationship between real GDP per capita and measures of environmental deterioration such as SO_2 and CO_2 emissions. Nevertheless, empirical evidence either utilising time series and panel data for a set of nations on the EKC hypothesis differ from nation to nation (Magazzino, 2015, 2016). The latter applies to the individual country studies conducted as well. Additionally, the results obtained are also not uniform across pollutants. This has created two problems being faced by environmental policymakers. The first problem is to ensure that useful knowledge informs policy without being misused or distorted and the second problem is to understand how to respond to this knowledge (Boehmer and Christiansen, 1994). The second strand focusses on the connection between energy consumption and economic output. The third and last strand is a combined approach of these two methods which studies the dynamic relationships between energy consumption, economic growth and environmental pollutants collectively (Acaravci and Ozturk, 2010; Kasman and Duman, 2015).

The various greenhouse gases (GHGs) which cause the global climate change, CO_2 is not the most ubiquitous. However, its existence is closely related to human activities such as transportations, deforestation, clearing lands for agricultural purposes, combusting fossil fuels, and cement production, which astronomically increased after the industrial revolution. Economists and scientists concur on the fact that increasing the amount of CO_2 emissions worsen climate change and environmental problems. Alternatively, the human influence on climate change and the environment is a substantial challenge. This is the reason initiatives to decrease CO_2 were brought to international stage through the efforts of the United Nations (UN).

Growth and development economists are worried about the continued increases in production in economies while environmental issues are evolving and intensifying. In other words, growth economists have been concerned with the economic situation because of the scarcity of natural resources (Kaika and Zervas, 2013). The scarcity of natural resources in the face of increasing production in various economies has aroused the interests of economists and environmentalists alike. This conflict has yielded the EKC extrapolated from empirical research of growth and trade economists (Grossman and Krueger, 1991; Shafik and Bandyopadhyay, 1992; Panayotou, 1993). The EKC theorizes that environmental degradation increases at the initial stage of economic growth (see Figure 1). Nevertheless, when economic growth reaches a certain level, this process reverses. In other words, environmental degradation declines with the rise in economic growth. The plotted graph of income and environmental deterioration shows a bell-shaped or mostly called an inverted U-shape curve. Due to the similarity of this curve to the Kuznets curve, demonstrating the relationship between income and income inequality, it is named EKC (Panayotou, 1993; Dinda, 2004).

Figure 1: The EKC curve



Source: World wide web

Even though there has been plenty of studies on the relationship between environmental degradation and economic growth, empirical studies of Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Panayotou (1993) are accepted as cornerstones of the EKC hypothesis. In general air pollution, water pollution, CO_2 emissions, and deforestation are treated as environmental degradation and GDP per capita is treated as an indicator of economic growth in these studies. Energy use, population density, trade, civil liberties, and education are some of the explanatory variables added to the research in addition to income. Most of the theoretical and empirical studies support the validity of the EKC for local pollutants like sulfur dioxide (SO_2) emissions, wastewater discharge and carbon monoxide (CO) emissions (He and Richard, 2010). Nevertheless, the existence of the EKC for CO_2 emissions is still questionable. Aforementioned, CO_2 emissions are the most significant GHGs to mitigate the climate change because human activities primarily cause it. That is why this study tries to investigate the relationship between CO_2 emissions, income and energy consumption.

The EKC hypothesis emphasizes that environmental problems which mostly resulted from economic development can be avoided with sufficient economic growth in both developed and underdeveloped economies if the EKC is valid (Caviglia-Harris, Chambers and Kahn, 2009). Thus, the discussions about global environmental issues are biased to follow the EKC hypothesis. Environmentalists remark that economic growth has been devastating the environment, especially with higher energy demand, while economists claim that these environmental problems can be solved automatically eventually with economic growth itself even if it harms the environment at the beginning. Hence, the nexus between environmental change and economic growth has been breaking because the cause of the problem is offered as the solution.

The current study, therefore, aims to detect the inverted U-shape relationship between CO_2 emissions and income. Moreover, the energy pollution, energy consumption and economic growth nexus are examined as well.

Two studies have been carried out in Namibia on the determinants of energy demand (see De Vita, Endresen, and Hunt, 2006; Ziramba and Kavezeri, 2012). The relationship between economic growth energy consumption as well as environmental pollution and economic growth have been the subject of intense research in the last few decades. However, the results obtained have remained controversial and ambiguous. Even though many articles that examine the EKCs and energy consumption have been written in African countries, none have to this day been written on Namibia.

Besides the introduction, the outline of the rest of the article as given below. Section 2 provides a survey of economic literature on the relationship between CO_2 emissions, energy consumption and economic growth. Section 3 gives a brief explanation of the empirical methodology and data employed. Section 4 discusses the empirical findings, while Section 5 presents some concluding remarks and suggestions for future research.

2. Literature review

It should be noted that there has been increasing attention on the impact of economic growth on the environment since the last few decades of the previous century. Pioneering work in this area was done in the early 1990s by Grossman and Krueger (1991, 1995) which assessed the environmental impacts of the North American Free Trade Agreement. These studies found an inverted U-shaped relationship between measures of several pollutants and GDP per capita and this was confirmed by Shafik and Bandyopadhyay (1992) and Panayotou (1993). From a theoretical perspective, the EKC does not only depend on levels of per capita GDP but a series of other factors causing changes in economic growth that can affect the environment. According to the structural effect hypothesis economic development passes through the various states starting from agriculture development, to industrial development which is associated with high-pollution, and then finally information concentrated industry development which leads to the improvements in environmental quality (Stern, 2004; Magazzino, 2015, 2016) (see Figure 1). Hence, at a low-income level, only the high pollution technique of production can be used, but once a certain income level is surpassed cleaner technologies can be adopted which lower the degradation in the environmental quality. Further, some scholars attribute the demand factors to the cause of EKC (for example, Nasir and Rehman, 2011), which asserts that demand for a clean environment will be increased as the per capita income increases.

Beckerman (1992) stresses the need to grow the economy to obtain environmental improvement. Moreover, he claims that enduring short run ecological degradation would be associated with environmental improvements in the long term. This is because becoming wealthy is a guaranteed way to improve ecological well-being (Panayotou, 1993). Therefore, the EKC hypothesis claims that economic growth is the solution for environmental pollution rather than a hazard to the environment (Stern, Common, and Barbier, 1996). It is therefore debatable whether economic growth is a prerequisite for environmental improvement; or whether it is the primary culprit causing environmental degradation.

Although the debate about the connection between income and environmental deterioration commenced in the 1970s, the real debate started in 1991 when a pioneering empirical study was conducted. The ground-breaking study by Grossman and Krueger (1991) which analysed the North American Free Trade Agreement's impact on the environment does not even acknowledge the Club of Rome debate (Grossman and Krueger, 1991). The study by Grossman and Krueger (1991) proves that economic growth could reduce environmental damages. Their study examines the connection between Gross Domestic Product per capita as an income indicator and air pollutants which are SO_2 and Suspended Particulate Matter (SPM), as environmental indicators. This study also includes trade in its model and the data used cover various time periods for the 42 countries. The study analysed this relationship using the cubic form of GDP per capita and found that the EKC exists. They concluded that the economic gains from trade would not become detrimental to the environment as expected.

The other key studies on this relationship were carried out by Soytas and Sari (2007) and Ozturk and Acaravci (2010). Their results also support the notion that economic growth is a prerequisite for overcoming the problem of environmental degradation. Also, Shafik and Bandyopadhyay (1992) used ten different environmental indicators for 149 countries between 1960 and 1990 and applied the log-linear, log-quadratic and log-cubic polynomial functional forms of GDP per capita to estimate the EKC. They found that the two air pollutants confirm the validity of the EKC hypothesis while the other indicators did not. In contrast to Grossman and Krueger's findings, the latter ambiguous findings are apparent signs of the complexity of the relationship between growth and environment.

It should be noted that after these cornerstone studies, there is a growing body of literature about the EKC. Most of the studies after that depend on parametric approaches using polynomial functions. For instance, Holtz- Eakin and Selden (1995), investigated the relationship between per capita GDP and CO_2 per capita for 130 countries for the period 1951 and 1986 using panel data and parametric specification techniques. The studies confirmed the EKC for the quadratic specifications and N-shape EKC curve for the cubic formulation.

It should be noted that in the EKC literature many studies estimate the relationship between income and CO_2 emissions. The study by Shafik and Bandyopadhyay (1992), is the first one in this regard. In addition, some studies use various explanatory variables apart from per capita GDP, select different geographic locations and time periods, and employ a full range of econometric methods such as cross-sectional, time series and panel data estimation techniques. Table 1 summarises additional studies about EKC estimated by using CO_2 emissions as an environmental indicator.

Table 1: The literature reviews of selected EKC

Authors and Publication Year	Environmental and Macroeconomic Indicators	Country/Regions and Periods	Econometric Technique	Results
Pao and Tsai (2011)	CO_2 per capita, economic growth, energy consumption and FDI	BRICS countries: 1980-2007 except for Russia (1992-2007)	Time series log, cointegration, and ARDL methodology	The EKC is confirmed (inverted U-shape) in all the countries. Emissions are energy consumption elastic and FDI inelastic. Bi-directional causality between output and emissions, output and energy consumption and unidirectional causality running from energy to emissions.
Al-mulali and Sab (2012)	CO_2 per capita, Financial development, energy consumption	19 mixed countries: 1980-2008	Panel Data	Energy consumption causes increased economic growth and financial development. High development increases emissions.

Shahbaz, Hye, Tiwari, and Leitão (2013)	CO_2 per capita, economic growth, energy consumption, financial development and trade	Indonesia: 1975q1-2011q4	ARDL-VECM methodology	Energy consumptions and economic growth increase CO_2 emissions, while trade openness and financial development decrease it. Bi-directional causality between economic growth and CO_2 emissions. Financial development cause CO_2 emissions.
Salahuddin and Khan (2013)	CO_2 per capita, economic growth, energy consumption	Australia: 1965-2007	VAR in first differences and IRFs	No cointegration. Energy consumption positively impacts CO_2 emissions and GDP does not. Bi-directional causality between energy consumption and economic growth and no causality between CO_2 emissions and economic growth.
Islam, Shahbaz, Ahmed and Alam (2013)	Energy consumption, economic growth, population and financial development	Malaysia: 1971-2008	Causality using VRCM	Financial development can reduce energy use and increase energy efficiency. Economic growth and financial development cause energy consumption, but the population energy relationship only holds in the long run only.
Shahbaz, Mutascu, andAzim (2013)	CO_2 per capita, economic growth, energy consumption	Romania 1980-2010	ARDL bounds testing approach	The long-run relationship between economic growth, energy consumption, and energy pollutants. EKC is confirmed in both the short run and the long run. Energy consumption increases energy pollutants. Democracy and financial development reduce CO_2 emissions.
Kivyiro and Arminen (2014).	CO_2 per capita, economic growth, energy consumption and FDI	Six Sub-Saharan African Countries: 1980-2013. DRC, Kenya, South Africa, Zambia, Republic of Congo, Zimbabwe	ARDL and VECM	Cointegration was found in all countries. The EKC hypothesis is supported in DRC, Kenya, and Zimbabwe. FDI increase CO_2 emissions in some countries. Causality is running from other variables to CO_2 emissions.
Shahbaz, Khraief, Uddin, and Ozturk (2014)	CO_2 per capita, economic growth, energy consumption, trade openness	Tunisia: 1971-2010	ARDL and VECM	The long-run relationship between CO_2 per capita, economic growth, energy consumption, trade openness. The VECM and innovative accounting approaches confirm the EKC. Structural breaks detected.
Al-Mulali, Saboori, and Ozturk (2015)	Fossil fuel, energy consumption, capital; imports, exports, labour force	Vietnam: 1981-2011	ARDL methodology	Capital and imports increase pollution. Exports do not affect pollution. Fossil fuel energy consumption increases pollution, and renewable energy consumption does not affect reducing pollution. Increases in agricultural labour decrease pollution. EKC hypothesis is non-existent.
Tang and Tan (2015).	CO_2 per capita, economic growth, energy consumption and FDI	Vietnam: 1976-2009	Time series analysis and causality	The long relationship among variables. Energy consumption and income positively influence CO_2 emissions. EKC hypothesis of an inverted U-shaped relationship between CO_2 emissions and economic growth is supported. Bi-directional causality between CO_2 emissions and income and between FDI and CO_2 emissions. Energy consumption Granger-causes CO_2 emissions.
Ozturk and Al-Mulali (2015)	CO_2 emissions, income, governance and corruption, urbanisation, energy consumption and trade openness	Cambodia: 1996-2012	Generalised Method of Moments and Two-Stage Least Squares	EKC hypothesis was not confirmed. Poor governance and corruption increase pollution.
Begum, Sohag, Abdullah, and Jaafar (2015)	CO_2 per capita, economic growth, energy consumption and population growth	Malaysia: 1970-2013	ARDL bounds testing methodology	Between 1970-1980 per capita CO_2 emissions decreased with an increase in per capita GDP and the opposite was true between 1980 and 2009. The EKC hypothesis is not valid. Energy consumption and economic growth increase per capita carbon emission while population growth does not.
Dogan and Turkekul (2016)	CO_2 emissions, real output, energy consumption, financial	USA 1960-2010	Time series analysis and causality	The variables are cointegrated. Energy consumption and urbanization increase environmental degradation. The EKC is not confirmed. There is bidirectional causality between CO_2 and GDP, CO_2 and

	development, and trade openness			energy consumption, CO_2 and urbanization, GDP and urbanization and GDP and trade openness. There is no causality between CO_2 and trade openness; and CO_2 and financial development.
Javid and Sharif (2016)	CO_2 emissions, real output, energy consumption, financial development, and trade openness	Pakistan: 1972-2013	Time series analysis	The EKC hypothesis is confirmed. The CO_2 emissions were found to increase with income, energy consumption and financial development.
Shahbaz, M., Solarin, S. A., Hammoudeh, S., & Shahzad, S. J. H. (2017).	CO_2 emissions, biomass energy consumption trade openness, economic growth	Unites States of America: 1960-2016	The Bounds Testing Approach to Cointegration with Structural breaks	The EKC hypothesis is not confirmed. Biomass energy consumption lowers CO_2 emissions. Exports, imports, and trade openness do not increase CO_2 emissions. Feedback causality is observed between biomass energy consumption and CO_2 emissions. Economic growth Granger-causes CO_2 emissions.

3. Methodology and econometric specification

The theoretical underpinnings of the relationship between economic growth and energy consumption with emissions have been discussed in the previous section. The relationship between economic growth and energy pollutants is termed as environmental Kuznets curve. The EKC hypothesis reveals that economic growth increases energy emissions initially. The main reason is that the principal objective of public and private sectors is to support the pace of economic growth through their contribution by creating more jobs without caring about the environmental cost. Above a certain level of per capita income, the economy starts to adopt environment-friendly technology to enhance output in the country due to the rising demand of cleaner environment as people are more conscious now about environmental quality. This implies that the relationship between economic growth and energy emissions should be inverted U-shaped termed as environmental Kuznets curve (EKC).

Economic activity channel can discuss the relationship between energy consumption and energy emissions in the country. The energy literature points out that a consistent rise in economic growth increases the demand for energy to enhance output level that in return produces an elevated level of energy pollutants. For instance, Paul and Bhattacharya (2004), Ho and Siu (2007), Bowden and Payne (2010) and Nasir and Rehman (2011) have concluded that high economic growth is linked with high energy consumption which may increase the environmental degradation.

The existence of environmental Kuznets curve in the presence of energy consumption test has to be conducted by transforming the variables to natural logarithms. The log-linear specification is superior and gives consistent empirical findings, according to Shahbaz (2010). The estimated equation is modeled as:

$$LNCO_{2t} = \psi_1 + \psi_1 T + \psi_2 LNEG_t + \psi_3 LNEG_t^2 + \psi_4 LNEC_t + \mu_t \quad (1)$$

Where, $LNCO_{2t}$ is the natural log of energy emissions per capita, $LNEG_t(LNEG_t^2)$ is economic growth proxied by real GDP per capita (square of real GDP per capita), $LNEC_t$ is energy consumption per capita and μ_t is the residual term assumed to be normally distributed in time period t. The hypothesis of EKC reveals that the sign of ψ_2 is positive i.e. $\psi_2 > 0$ while that of ψ_3 is negative i.e $\psi_3 < 0$. It implies that economic growth increases energy emissions initially and reduces it when the economy has matured. Similarly, the rising energy demand will increase energy emissions if ψ_4 is positive i.e. $\psi_4 > 0$.

I have applied ARDL bounds testing approach to cointegration to test the existence of long-run relationship between economic growth, energy consumption and CO_2 emissions in case of Namibia using quarterly time series data from 1991 to 2016. The ARDL approach is superior to traditional techniques and is free from the problem of integrating order of the variables. This approach can be applied if variables are integrated at I(1), or I(0) or I(1)/I(0). Another merit of ARDL bounds approach is that it has suitable properties for small sample data sets like in case of Namibia. The dynamic error correction model (ECM) can be derived from the ARDL model through a simple linear transformation (Banerjee and Newman (1993). The error correction model integrates the short-run dynamics with the long-run equilibrium without losing information about long-run. The equations of unrestricted error correction methods for ARDL bounds approach are modeled as:

$$\Delta LNCO_{2t} = \phi_{10} + \phi_{12} LNCO_{2,t-1} + \phi_{13} LNEG_{t-1} + \phi_{14} LNEG_{t-1}^2 + \phi_{15} LNEC_{t-1} + \sum_{i=0}^{m} \phi_{1i} \Delta\phi_2 LNCO_{2,t-i} + \sum_{j=0}^{n} \phi_{1j} \Delta LNEG_{t-j} + \sum_{k=0}^{p} \phi_{1k} \Delta LNEG_{t-k}^2 + \sum_{l=0}^{q} \phi_{1l} \Delta LNEC_{t-l} + \xi_{1t} \quad (2)$$

The equations for $LNEG_t$, $LNEG_t^2$ and $LNEC_t$ are also specified in a similar fashion. However, since these other three equations are not important in proving the existence of the EKC they have been left out here. The decision about cointegration among the variables depends upon the critical bounds generated by Pesaran et al. (2001). The hypothesis of no cointegration in

Equation 2 is $\phi_{12} = \phi_{13} = \phi_{14} = \phi_{15} = 0$. Alternatively, the hypothesis for the existence of cointegration is $\phi_{12} \neq \phi_{13} \neq \phi_{14} \neq \phi_{15} \neq 0$. The decision is in favour of cointegration if the upper critical bound is less than the computed F-statistic. There is no cointegration between the variables if the computed F-statistic is less than the lower critical bound (LCB). If the computed F-statistic lies between the lower and the upper critical bounds, then the decision about cointegration is indeterminate.

The goodness of fit of ARDL bounds testing approach is investigated by applying the diagnostic and stability tests. The diagnostic tests are applied to test the serial correlation, functional form, the normality of error term and heteroscedasticity in the model. The cumulative sum of recursive residuals (CUSUM) and the cumulative sum of squares of recursive residuals (CUSUMSQ) have been conducted to test the stability of ARDL parameters.

To carter for the shortcomings of the bivariate Granger causality, the current study employs the multivariate Granger causality model within an autoregressive distributed lag (ARDL) bounds testing approach by Pesaran and Shin (1999). The latter approach was initially developed by Pesaran and Shin (1999) and later extended and improved by Pesaran et al. (2001). Following Narayan and Smith (2008), Odhiambo (2011), Nyasha and Odhiambo (2015) and Sunde (2017), a multivariate causality model for this study, which is based on an error correction mechanism can be expressed as follows:

$$\Delta LNCO_{2t} = \alpha_{01} + \sum_{i=1}^{m} \alpha_{11} \Delta LNCO_{t-1} + \sum_{j=1}^{n} \alpha_{12} \Delta LNEG_{t-1} + \sum_{k=1}^{p} \alpha_{13} \Delta LNEG_{t-1}^{2} + \sum_{l=1}^{q} \alpha_{14} \Delta LNEC_{t-1} + \lambda_1 ECT_{t-1} + \varepsilon_{1t} \quad (3a)$$

$$\Delta \mathrm{LNEG} = \beta_{02} + \sum_{i=1}^{m} \beta_{21} \Delta LNEG_{t-1} + \sum_{j=1}^{n} \beta_{22} \Delta LNCO_{2,t-1} + \sum_{k=1}^{p} \beta_{23} \Delta LNEG_{t-1}^{2} + \sum_{l=1}^{q} \beta_{24} \Delta LNEC_{t-1} + \lambda_2 ECT_{t-1} + \varepsilon_{2t} \quad (3b)$$

$$\Delta LNEG^2 = \delta_{03} + \sum_{i=1}^{m} \delta_{31} \Delta LNEG^2{}_{t-1} + \sum_{j=1}^{n} \delta_{32} \Delta LNEG_{t-1} + \sum_{k=1}^{p} \delta_{33} \Delta LNCO_{2,t-1} + \sum_{l=1}^{q} \delta_{34} \Delta LNEC_{t-1} + \lambda_3 ECT_{t-1} + \varepsilon_{3t} \quad (3c)$$

$$\Delta LNEC = \theta_{04} + \sum_{i=1}^{m} \theta_{41} \Delta LNEC_{t-1} + \sum_{j=1}^{n} \theta_{42} \Delta LNEG_{t-1} + \sum_{k=1}^{p} \theta_{43} \Delta LNEG_{t-1}^{2} + \sum_{l=1}^{q} \theta_{44} \Delta LNCO_{2,t-1} + \lambda_4 ECT_{t-1} + \varepsilon_{4t} \quad (3d)$$

Where, ε_{it} are white noise residual terms. The estimates of the ECT_{t-i} shows the speed of convergence from the short run towards the long run equilibrium path in all models depending upon the sign of the coefficient of ECT_{t-i}. According to Narayan and Smith (2004) and Odhiambo (2011, 2015), even though the existence of a long run relationship between the variables suggests that there must be Granger causality between these variables in at least one direction, it does not show the direction of causality between these variables. According to Narayan and Smith (2004), Odhiambo (2011, 2015) and Sunde (2017, 2018) the causal impact is measured through the F-statistics on the explanatory variables, while the long run causal impact is measured through the error correction term. It should be noted that in spite of the fact that the error correction term has been incorporated in all the four equations of the model [Equations (3a) to (3d)], only equations where the null hypothesis of no cointegration is rejected, will be estimated with an error-correction term (Odhiambo, 2011, 2015; Sunde, 2017, 2018)

The data on carbon emissions per capita, real GDP per capita and energy consumption per capita have been collected from world development indicators (CD-ROM, 2017). The data span of the study is from 1991: q1 up to 2016: q4.

4. Empirical results and discussion

4.1 Stationarity tests

The first step taken in the estimation of the results was to draw some trend diagrams for the variables used in the study. Figure 1 illustrates that all the variables have trends that increase with time which suggest that all the variables are non-stationary in levels. The informal test results are corroborated by conducting the formal Augmented Dickey-Fuller (ADF) and Phillips Perron (PP) tests whose results are reported in Table 1 below. Table 1 shows the Augmented Dickey-Fuller (ADF) and Phillips-Peron (PP) test results of the non-stationarity for all variables. The non-stationarity test results show that all the variables were confirmed stationary after differencing them once. Although the ARDL test does not need the pre-testing of variables to be done, the unit-root tests give guidance as to whether ARDL procedure is applicable or not, as it is only applicable for the analysis of variables that are integrated of orders not more than one. In this case, the variables are all integrated of order 1. Therefore, the ARDL bounds testing procedure can be performed.

Figure 1: Trend diagrams of variables

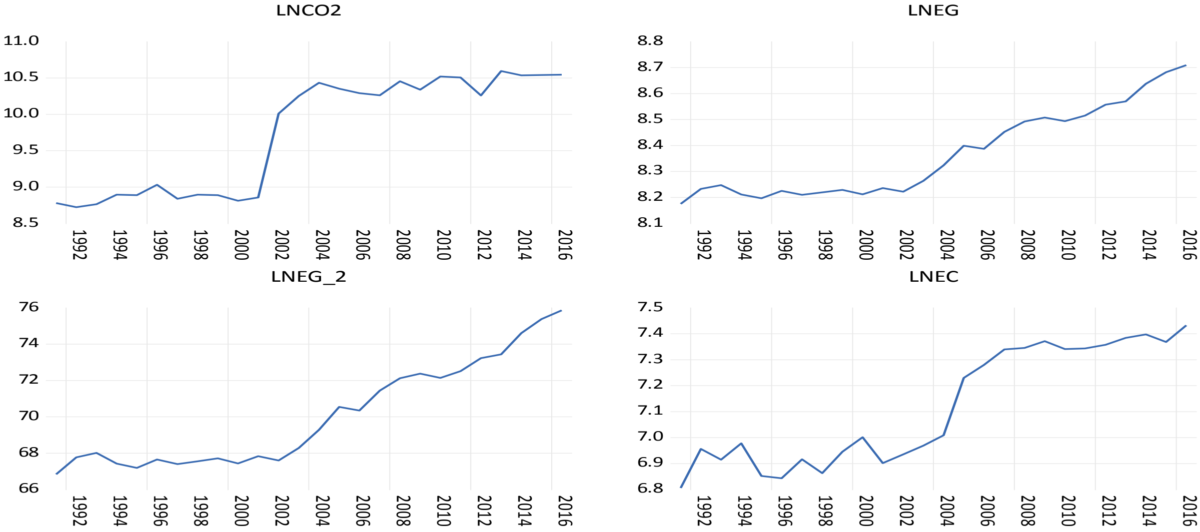


Table 1: The ADF and PP tests results

Variable	*Model*	*ADF unit root test*		*P-P unit root test*	
		t-statistic	*Prob. value*	*t-statistic*	*Prob. value*
$LNCO_2$	Constant	-0.587120	0.8684	-0.378554	0.9084
	Const & trend	-1.814643	0.6954	-1.955817	0.6225
LNEC	Constant	-0.786227	0.8057	-0.746949	0.8167
	Const & trend	-2.005116	0.5704	-2.011433	0.5672
LNEG	Constant	-0.684608	0.8459	-0.270645	0.9250
	Const & trend	-1.796815	0.7041	-1.099372	0.9264
$LNEG^2$	Constant	1.287950	0.9978	1.279917	0.9977
	Const & trend	-1.077870	0.9130	-1.023203	0.9223
$\Delta LNCO_2$	Constant	-3.267276**	0.0185	-5.886***	0.0000
	Const & trend	-5.385341***	0.0000	-13.98***	0.0000
ΔLNEC	Constant	-5.7506***	0.0001	-5.714***	0.0001
	Const & trend	-5.6426***	0.0006	-5.615***	0.0007
ΔLNEG	Constant	-3.086181**	0.0301	-5.047***	0.0000
	Const & trend	-4.617895***	0.0011	-12.98***	0.0000
$\Delta LNEG^2$	Constant	-4.201608***	0.0034	-4.205***	0.0034
	Const & trend	-5.194399***	0.0017	-5.265***	0.0015

Note: ** and *** denote statistical significance at 5%, and 1% levels, respectively

4.2 Testing for cointegration

Since the study makes use of the ARDL-ECM Granger causality tests, later on, it is appropriate to do the cointegration tests for the ARDL model. The cointegration results are shown in Table 2. In all the cases, the calculated F-statistics are higher than the critical values at all the levels of significance. This implies that there are cointegrating relationships among energy consumption, GDP per capita, GDP per capita squared and CO_2 emissions in the four models in the case of Namibia over the study period 1991: q1-2016: q4. This implies that there are possible causal relationships among these variables included in the ARDL model. The four ARDL equations were found free of the normality, heteroscedasticity and misspecification problems since all the probability values are greater than 5 percent as shown in Table 2.

Table 2: The ARDL cointegration analysis

<table>
<tr><td colspan="3">Estimated Models</td><td>Lag length</td><td>F-statistics</td><td>$\chi^2 Normal$</td><td>$\chi^2 Arch$</td><td>$\chi^2 Reset$</td></tr>
<tr><td colspan="3">F($LNCO_2$ | LNEC, LNEG, $LNEG^2$)</td><td>3,4,2,4</td><td>4.934185</td><td>0.4173</td><td>0.2034</td><td>0.8418</td></tr>
<tr><td colspan="3">F(LNEG | $LNCO_2$, LNEC, $LNEG^2$)</td><td>4,4,4,4</td><td>6.911826</td><td>0.9581</td><td>0.1765</td><td>0.8881</td></tr>
<tr><td colspan="3">F($LNEG^2$ | $LNCO_2$, LNEC, $LNEG^2$)</td><td>4,3,3,4</td><td>6.897646</td><td>0.2341</td><td>0.8795</td><td>0.9763</td></tr>
<tr><td colspan="3">F(LNEC | $LNCO_2$, LNEG, $LNEG^2$)</td><td>4,3,4,4</td><td>16.10510</td><td>0.0588</td><td>0.7500</td><td>0.5207</td></tr>
<tr><td colspan="8">Asymptotic critical values
Pesaran et al. (2001, 300). Table CI (3) Case 3</td></tr>
<tr><td colspan="2">10%</td><td colspan="2">5%</td><td colspan="2">2.5%</td><td colspan="2">1%</td></tr>
<tr><td>I(0)</td><td>I(1)</td><td>I(0)</td><td>I(1)</td><td>I(0)</td><td>I(1)</td><td>I(0)</td><td>I(1)</td></tr>
<tr><td>2.37</td><td>3.20</td><td>2.79</td><td>3.67</td><td>3.15</td><td>4.08</td><td>3.65</td><td>4.66</td></tr>
</table>

4.3 The long-run results

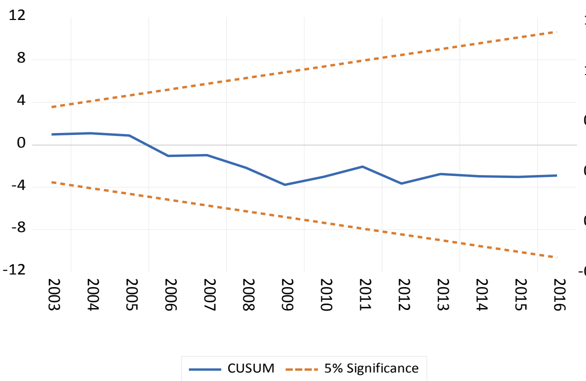
After proving the robustness of the long run relationship between these variables and the long run marginal impacts of real GDP per capita and energy consumption I employed OLS approach to investigate whether the latter variables in Namibia explain CO2 emissions. It should be noted that the results reported in Table 2 highlight that energy consumption is a major contributory factor to energy pollutants and it is significant at the 5 percent level of significance. In addition, a 1 percent rise in energy consumption is associated with a 0.266 increase in CO_2 emissions. These findings support the view by Wolde-Rufael (2006) that energy consumption highly contributes to energy pollutants as compared to other indicators of energy.

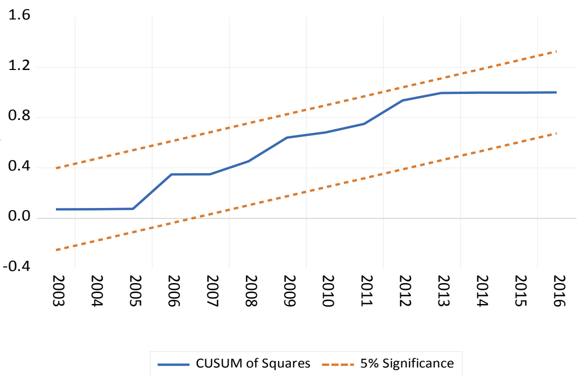
The long-run model results also show that the impact of linear and nonlinear terms of real GDP per capita is positive and negative, respectively. The results show that a 1 percent increase in economic growth leads to a 10.78 increase in CO_2 emissions. The coefficients of the linear and nonlinear terms are 10.7847 and -4.32233, respectively, and they are both significant at 10 percent level of significance. It should be noted that the significance of both linear and non-linear terms of real GDP per capita provide the empirical evidence of an inverted-U shaped relationship between GDP per capita and CO_2 emissions. The latter relationship is the one that results in the "so-called Environmental Kuznets curve" (EKC). This empirical evidence provides the support for EKC revealing that CO_2 emissions increase at the initial stage of economic growth and decline after a threshold point is surpassed. These results support findings by Kasman and Duman (2015), Govindaraju and Tang (2013), Jalil and Mahmud (2009), Fodha and Jayanthakumaran et al. (2012), Halicioglu (2009), Lean and Smyth (2010) and Nasir and Rehman (2011).

Table 3: The long run and short run results

The short-run results				
Dependent Variable = $LNCO_{2t}$				
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	
$LNEG_t$	10.7847	0.080289	1.837646*	
$LNEG_t^2$	-4.32233	0.756711	-1.846444*	
$LNEC_t$	0.266381	0.225429	2.412289**	
Constant	24.25016	5.103702	1.917104*	
The short-run results				
Dependent Variable = $\Delta LNCO_{2t}$				
Variable	*Coefficient*	*Std. Error*	*t-Statistic*	*Prob.*
$\Delta LNEG_t$	0.04928	0.045527	1.88393**	0.0459
$\Delta LNEG_t^2$	-0.743834	0.369881	-2.085575**	0.0296
$\Delta LNEC_t$	0.823207	0.054331	3.289024***	0.0054
ECT_{t-1}	-0.536359	0.015190	-6.033633***	0.0000
Diagnostic tests		*F-Statistic*		*P-value*
χ^2 *SERIAL*		0.149671		0.9279
χ^2 *JARQUE BERA*		1.148180		0.5632
χ^2 *ARCH*		0.504221		0.4777
χ^2*RESET*		17.95336		0.4456

Figure 2: The CUSUM and CUSUM of squares results





The short-run dynamics are reported in the lower segment of Table 2, and the results indicate that energy consumption is also the main contributor to CO_2 emissions and it is significant at 1 percent level. The coefficients of linear term of real GDP per capita and nonlinear (i.e. the squared term of real GDP per capita are positive and negative, respectively). These estimates are significant at the 5 percent significance level. This further confirms the existence of ECK which corroborates the long run ECK in case of Namibia. The short-run estimates are less than long-run estimates which shows the reliability and stability of estimated results.

The lagged ECM term estimated coefficient is -0.536359, and it is significant at the 1% level. This result shows that there is a long run relationship among the variables included in the model. This further suggests that changes in CO_2 emissions from the short run to the long run are corrected by 53.64 percent each year. It should be noted that the significance of lagged error correction term further confirms the established long-run relationship between energy consumption, economic growth and CO2 emissions.

Table 2 summarises the results of the error based diagnostics tests such as normality, autocorrelation, heteroscedasticity and model specifications. Findings suggest that the short-run model results are robust and hence pass all diagnostic tests. The evidence illustrates that error term is normally distributed and there is an absence of serial correlation. There is no evidence of autoregressive conditional heteroscedasticity. The short run model has passed Ramsey RESET test which confirms that the functional form of the short-run model is correctly specified. Shahbaz et al. (2013) suggest that the stability of long run and short run parameters can be tested by applying CUSUM and CUSUMsq tests. To that effect, the cumulative sum (CUSUM) and the cumulative sum of squares (CUSUMsq) tests have been employed to test for parameter stability. The results are shown in Figure 2. The graph (blue line) should lie within the bounds if the parameters are stable (Pesaran et al., 2001). The graphs of CUSUM and CUSUMsq show that both the long-and-short runs parameters are stable at the 5 percent level of significance.

4.5 Granger causality tests

The presence of cointegration among the variables implies that causality relationships must exist from at least one direction. The direction of the relationship between energy consumption, GDP per capita, GDP per capita squared and CO_2 emissions develop policies to increase economic growth by controlling environment from degradation and utilize energy efficient technologies imported from advanced countries. I applied Granger causality test within the ARDL-ECM framework to detect the causality between the variables. Tables 4 and 5 report the results of ARDL-ECM Granger causality analysis. The long-run causality is captured by a significant t-test on a negative coefficient of the lagged error correction term (ECT_{-1}). The jointly significant LR test on the lagged explanatory variables shows short-run causality.

Table 4: The ARDL-ECM Granger causality analysis

Dependent variable	*Short run causality (p-value)*				*Long run (t-statistic)*
	$\Delta LNCO_{2t}$	$\Delta LNEG_t$	$\Delta LNEG^2$	$\Delta LNEC_t$	ECT_{t-1}
$\Delta LNCO_{2t}$	-	2.395** (0.0358)	3.613** (0.0386)	12.456*** (0.0001)	0.435*** (-3.833)
$\Delta LNEG_t$	2.324*** (0.0029)	-	9.4657*** (0.0000)	5.297** (0.0137)	0.523*** (-3.513)
$\Delta LNEG^2$	0.572* (0.0665)	4.546*** (0.0005)	-	0.957 (0.4657)	0.438*** (-3.239)
$\Delta LNEC_t$	4.256** (0.0355)	4.546 (0.1567)	0.4112 (0.1735)	-	0.438*** (-3.239)

Note: *, ** and *** denote statistical significance at 10%, 5%, and 1% levels, respectively

Table 5: Summary of ARDL-ECM Granger causality results

Direction of causality	*Short run*	*Long run*
LNEG Granger causes $LNCO_2$	Significant at 5%	Significant at 1%
$LNEG^2$ Granger causes $LNCO_2$	Significant at 5%	
LNEC Granger causes $LNCO_2$	Significant at 1%	
$LNCO_2$ Granger causes LNEG	Significant at 1%	Significant at 1%
$LNEG^2$ Granger causes LNEG	Significant at 1%	
LNEC Granger causes LNEG	Significant at 5%	
$LNCO_2$ Granger causes $LNEG^2$	Significant at 10%	Significant at 1%
LNEG Granger causes $LNEG^2$	Significant at 1%	
LNEC Granger causes $LNEG^2$	No causality	
$LNCO_2$ Granger causes LNEC	Significant at 5%	Significant at 1%
LNEG Granger causes LNEC	No causality	
$LNEG^2$ Granger causes LNEC	No causality	

The short and long-run Granger causality results are summarised below:

- There is bi-directional causality between economic growth and carbon emissions.
- There is bidirectional causality between the square of economic growth and carbon emissions.
- There is bidirectional causality between energy consumption and carbon emissions.
- There is unidirectional causality between economic growth and energy consumption running from energy consumption to economic growth.
- There is independence between energy consumption and the square of economic growth.
- In the long run, there is bidirectional causality between carbon emission and economic growth, carbon emissions and the square of economic growth and carbon emissions and energy consumption.

5. Conclusions and policy implications

This article investigated the dynamic linkages between energy consumption, economic growth and carbon emissions in the case of Namibia over the period of 199:q1-2016:q4. The study applied the ADF and the PP unit root test to test the non-stationarity of the variables. Also, the ARDL bounds testing approach to cointegration was employed to investigate the long run relationship between the variables. The current study has significant policy implications for the Namibian economy. The findings confirmed that all the variables are cointegrated which implies that there is a long run relationship among them and that they were robust. Energy consumption was proven to be the primary contributor to carbon emissions (energy pollutants). An increase in economic growth raises energy consumption. The results also confirmed the existence of the environmental Kuznets curve (EKC) in both long run and the short run in Namibia. Additionally, the results also show bi-directional causality between economic growth and carbon emissions, the square of economic growth and carbon emissions and energy consumption and carbon emissions. The results also show that there is unidirectional causality between economic growth and energy consumption running from energy consumption to economic growth. Lastly, the results show independence between energy consumption and the square of economic growth in the short run.

Even though there are many contradictory results about the EKC in literature, the current study confirms the existence of the EKC. It should be noted that the findings depend on many criteria such as the pollutants considered, the econometric techniques used, and the period studied, among others. These results imply that economic growth can be a remedy for environmental degradation which means that the exploitation of natural resources for the sake of economic growth can be accepted until the turning point of the EKC curve is reached. However, some studies have shown that deterioration of the ecosystems may persist even after reaching a specific income level when irreversible damages have already been done (see Özokcu and Özdemir, 2017). It should be noted that this persistence is of paramount importance especially for CO_2 emissions and its long-run effect on the environment. This means that actions to slow down the release of CO_2 emissions and the raising of awareness about environmental concerns should not be postponed until the economy reaches high-income levels. Moreover, global, regional and local policies are required independently from income levels to combat potential hazards posed by climate change, or at least to adapt to climate change.

It should be noted that there are many explanations for the association between income and environmental quality. One of the explanations is that households tend to opt for better environmental quality as income goes up (Yandle et al., 2002; Dinda, 2004; Bo, 2011). This means that there is a direct relationship between income per capita and the consumption of pollution-intensive goods (Pearce, March 2003; Roca, 2003).

Finally, the current study has some limitations. One of them is the availability of good quality data for most emerging and developing economies. Data availability is more crucial for local scale analysis to induce policy creations. This problem can be counteracted with the help of international institutions and organisations. In addition, more sophisticated econometrics methods such as panel/pooled data analysis can be employed to obtain better and more reliable results.

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