The Effects of Energy Consumption, Democracy, Regulatory Quality and Globalization on the Environment in South Africa

Maryam Abu-Goodman

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Approval of the Institute of Graduate Studies and Research

Prof. Dr. Ali Hakan Ulusoy
Director

I certify that this thesis satisfies all the requirements as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Mehmet Balcılar
Chair, Department of Economics

We certify that we have read this thesis and that in our opinion it is fully adequate in scope and quality as a thesis for the degree of Doctor of Philosophy in Economics.

Prof. Dr. Hasan Güngör
Supervisor

Examining Committee

1. Prof. Dr. Alper Aslan
2. Prof. Dr. Hasan Güngör
3. Prof. Dr. İlhan Öztürk
4. Prof. Dr. Sevin Uğural
5. Asst. Prof. Dr. Nuru Giritli

ABSTRACT

This study provides a macroeconomic analysis of the effects of energy consumption, democracy, and globalization on environmental degradation in South Africa. The econometrics tools used in the analysis are based on linear and nonlinear methods. The first chapter provides the introduction and motivation for the study. The second chapter investigates the dynamic effects of energy consumption, democracy, and globalization on environmental degradation in the context of the environmental Kuznets curve (EKC) hypothesis for South Africa between 1971 and 2014. To this end, the study applies the combined Bayer-Hanck cointegration test and Fully Modified Ordinary Least Squares (FM-OLS) estimator. The result confirms the presence of cointegration among the variables and thus validates the EKC hypothesis for South Africa.

The third chapter uncovers the role of regulatory quality, energy use, and globalization in the conventional environmental Kuznets curve (EKC) for South Africa by incorporating structural breaks in the series based on quarterly frequency data between 1996:Q1 and 2016:Q4. Applying the Autoregressive Distributed Lag (ARDL) model, all the variables are cointegrated. The results suggest the validity of the EKC hypothesis in South Africa. The results further reveal that the structural break years are statistically insignificant. The causality result establishes a causal link flowing from all the variables to the ecological footprint in the long run. In the short run, economic growth and energy use Granger-cause regulatory quality.

The fourth chapter deviates from the existing literature by disentangling the variables into their positive and negative changes to capture asymmetric and dynamic multiplier effects of economic growth, globalization, and renewable energy on environmental sustainability within the framework of the autoregressive distributed lag (ARDL) model. In doing this, the study uses South African data for the period 1990 to 2018 and the results show that CO_2 emissions respond differently to the positive and negative shocks in the variables. The thesis, therefore, provides insightful policy suggestions to enhance environmental sustainability in South Africa.

Keywords: Energy Consumption; Renewable Energy; Democracy; Economic Growth; Environmental Degradation; CO_2Emissions; Regulatory Quality; ARDL; NARDL; Cointegration; Long- and Short-run; South Africa

ÖZ

Bu çalışma, Güney Afrika'da enerji tüketimi, demokrasi ve küreselleşmenin çevresel tahribat üzerindeki etkilerinin makroekonomik analizini sunmaktadır. Analizde kullanılan ekonometrik modeller, doğrusal ve doğrusal olmayan yöntemlere dayanmaktadır. Birinci bölümde, çalışmanın giriş ve motivasyonu yer almaktadır. İkinci bölümde, 1971-2014 yılları arasında Güney Afrika'da enerji tüketimi, demokrasi ve küreselleşmenin çevre üzerindeki dinamik etkisi Çevresel Kuznets eğrisi (EKC) kapsamında incelenmektedir. Bu amaçla, Bayer-Hanck eşbütünleşme testi ve Tamamen Geliştirilmiş En Küçük Kareler (FM-OLS) yöntemi uygulanmıştır. Sonuçlar, değişkenler arasında eş-bütünleşme ilişkisinin varlığını doğrulamakta ve dolayısıyla EKC hipotezinin Güney Afrika için geçerliliğini onaylamaktadır.

Üçüncü bölüm, 1996:Q1-2016:Q4 dönemleri çeyreklik verilerden oluşan serilere yapısal kırılmalar dahil ederek, Güney Afrika için düzenleyici kalite, enerji kullanımı ve küreselleşmenin geleneksel çevresel Kuznet eğrisi (EKC)'ndeki rolünü ortaya koymaktadır. Otoregresif Dağıtılmış Gecikme (ARDL) modeli uygulanarak, tüm değişkenlerin eş-bütünleşik olduğu tespit edilmiştir. Analiz sonuçları, Güney Afrika için EKC hipotezinin geçerliliğini ortaya koymaktadır. Bununla birlikte, küreselleşmenin etkisi uzun vadede zayıfken, düzenleyici kalitenin etkisi kısa dönemde zayıftır. Ampirik sonuçlar, ayrıca, yapısal kırılma yıllarının istatistiksel olarak anlamsız olduğunu ortaya çıkarmaktadır. Nedensellik sonuçları, uzun dönemde tüm değişkenlerden ekolojik ayakizine doğru nedensel bir bağlantı kurulduğunu göstermektedir. Kısa vadede ise Granger nedensellik testi, nedenselliğin

ekonomik büyüme ve enerji kullanımından kaliteli yasal düzenlemelere doğru olduğuna dair bulgu yapmaktadır.

Dördüncü bölüm, Otoregresif Dağıtılmış Gecikme (ARDL) modeli çerçevesinde ekonomik büyüme, küreselleşme ve yenilenebilir enerjinin çevresel sürdürülebilirlik üzerindeki asimetrik ve dinamik çarpan etkilerini tespit etmek için değişkenleri pozitif ve negatif değişimlerine ayırması yönüyle mevcut literatürden farklılık göstermektedir. Çalışmada 1990-2018 dönemi için Güney Afrika verileri kullanılmakta ve bulgular, Co2 emisyonlarının değişkenlerdeki pozitif ve negatif şoklara farklı tepkiler verdiğini göstermektedir. Bu nedenle, tez Güney Afrika'da çevresel sürdürülebilirliği güçlendirmek için detaylıpolitika önerileri sunmaktadır.

Anahtar Kelimeler: Enerji Tüketimi;Yenilenebilir Enerji; Demokrasi; Ekonomik Büyüme; Çevresel Tahribat; Karbon Emisyonları; Düzenleyici Kalite; ARDL; NARDL; Eşbütünleşe; Uzun ve Kısa Dönem; Güney Afrika

DEDICATION

To Almighty God

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LIST OF SYMBOLS AND ABBREVIATIONS

Δ	Difference Operator
ADF Test	Augmented Dickey-Fuller Test
AIC	Akaike Information Criterion
ARDL	Auto Regressive Distributed Lag
CO_2	Carbon Dioxide Emissions
DEM	Democracy
EG	Economic Growth
EG^2	Square of Economic Growth
EIA	Energy Information Administration
EC	Energy Economics
FEVDs	Forecast Error Variance Decompositions
F-Test	Fisher-Test
GDP	Gross Domestic Product
GDP^2	Square of GDP
GLO or GI	Globalization
Ln or Log	Natural Logarithms
NARDL	Nonlinear ARDL
OECD	Organization for Economic Cooperation and Development
PP	Phillips-Perron Test
P-value	Probability Value
RE	Renewable Energy
SIC	Schwarz Bayesian Information Criterion
T-stat	Test Statistic

UECM	Unrestricted Error Correction Model
VAR	Vector Autoregression
VECM	Vector Error Correction Model
WDI	World Development Indicators

Chapter 1

INTRODUCTION

The link between environmental quality, energy consumption, globalization, and regulatory quality is of interest in South Africa considering their leading position in CO_2 emissions in Africa and their giant strides to develop among other African countries which suggest massive use of energy. Thus, this study intends to empirically confirm the status of the relationship between environmental degradation and the dualfactor of globalization and regulatory quality while accounting for economic expansion and energy utilization in South Africa. The overdependence on fossil fuels (oil, gas, and coal) as the main sources of energy for driving economic growth has contributed significantly to global warming and environmental degradation.

The objective of the study, therefore, is to examine the dynamic impacts of energy utilization, quality, globalization, democracy, and regulations on the environment in the context of the EKC hypothesis for South Africa. Even though a good number of researches on EKC have been undertaken effectively for South Africa, by incorporating variables like trade, foreign direct investment, financial development, urbanization, education, population increase, agriculture, and capital investments' there is still a need to better understand the key role of democracy on environmental quality. Therefore, this study offers several contributions to the literature: first, the paper incorporates the impacts of energy utilization, globalization democracy, and regulatory quality on carbon dioxide emissions and tests the validity of the EKC hypothesis for South Africa.

Objectively, the roles of regulatory quality and globalization in the conventional EKC in South Africa were assessed. This is important at this stage because globalization is rapidly helping the desires of many developing nations for sustained economic growth, but environmental pollution has become a global problem, which is being buttressed by globalization. Therefore, as economies are seeking to strike a balance between this good and bad, the study helps us understand the role of regulations in this mission to reduce global warming. This will enable policymakers to develop an effective institutional framework that ensures effective regulatory quality. With this knowledge, Africa can also review their priority policy rules and utilize globalization for the benefit of the environment by reducing the effects of human activities, which damage the environment in the quest for economic growth and development.

However, it is on record how important energy is in the economic development process, for both developed and developing nations. Energy consumption, regulatory quality, and globalization have positive impacts on people's general quality of life, living standards, and socioeconomic progress. Furthermore, the relationshipbetween energy utilization and economic expansion is not independent of interdependence among economies and political institutions that oversee the policymaking process.

As this economy aims toward growth and development, interaction and integration with other economies of the world is inevitable. Therefore, among the important socio-economic factors connecting and affecting both developing and developed countries, the increasing wave of globalization has also had its diverse influence on South African economic activities. This dictates the direction of production, the technology used in production, industrialization, urbanization and transportation.

Grossman and Krueger (1991), research was the first to establish a link between economic expansion and the environment, indicating environmental degradation rises at the beginning phase of economic' expansion, and subsequently starts to drop at the latter stage. Although globalization is adjudged to be beneficial to economies in their growth process (Shahbaz, 2019), energy consumption increases with a growing economy and as a tool of economic expansion, CO_2 emission is bound to increase. The argument of the opponents of globalization implies that globalization cannot ensure sustainable development because it only engenders economic activities at the expense of the future generation's welfare since environmental quality is given away to achieve the improved economic activity. Countries have become more agitated over growing pollutant activities in the economy as this has become a trade-off between increased output and a conducive environment in developing countries. However, the kind of institutions that govern the process of policy making have become major determinants of pollution emitting activities in society, this will depend on effective enforcement of environmentally friendly policies and adequate regulatory quality.

The suspected U-shaped relation between globalization and environmental degradation follows the underlying forces of three effects of globalization on the economy (Ling et al., 2015; Rafindadi& Usman, 2019; Shahbaz, 2019). First, through the scale effect, globalization leads to massive energy consumption through accelerated economic growth at the initial stage of globalization. Consequently,

CO_2emissions will also rise (Cole, 2006; Dedeoğlu& Kaya, 2013). Second, through the composition effect, the share of carbon-intensive inputs in production begins to decline as structural changes begin to occur in productive activities. For example, society attempts to shift from carbon-intensive activities, driven by huge energy consumption in agriculture, transport and service, to information-intensive activities such as replacing transportation with electronic communication (Stern, 2007).

Finally, through the technique effect, there is a total paradigm shift in production processes as part of the benefits of globalization, such that importation of knowledge and technological advancement can boost production and also help to reduce energy consumption, and thus, emissions of pollutant substances also decrease (Antweiler, et al., 2001; Jena and Grote, 2008).Therefore, this thesis adds to the body of literature by looking into linear and nonlinear relations of the implications of democracy, economic expansion, and globalization, with renewable energy utilization on the sustainable environment in South Africa through the autoregressive distributed lag model (NARDL) model techniques.

Chapter two examines the dynamic impacts of energy utilization, globalization, and democracy, on CO_2 emission in the relation to EKC hypothesis in South Africa from 1971 to 2014. Even though a good number of researches on EKC have been undertaken effectively for South Africa by incorporating variables like foreign direct investment, financial development, trade, urbanization, populace expansion, education, agriculture, and capital investment there is still a need to better understand the key role of democracy on environmental quality.

Chapter three adds to the body of literature by uncovering the roles of energy utilization, and regulatory quality, with globalization in the classical environmental Kuznets curve in South Africa by including a structural break to the sequence upon quarterly frequency data from 1996:Q1 to 2016:Q4. By using the Autoregressive Distributed Lag (ARDL) model, itdemonstrates that the variables are cointegrated. The findings point to the EKC hypothesis' applicability in South Africa.

Chapter 4 deviates from the existing literature by disentangling the variables and their alterations, both positive and negative to capture asymmetric and dynamic multiplier effects of economic expansion, and globalization, with renewable energy on environmental sustainability within the parameters of the autoregressive distributed lag (ARDL) model.

Chapter 2

MODELING ENVIRONMENTAL DEGRADATION IN SOUTH AFRICA: THE EFFECTS OF ENERGY CONSUMPTION, DEMOCRACY, AND GLOBALIZATION USING INNOVATION ACCOUNTING TEST

2.1 Introduction

Globally, environment-related problems associated with climate change have become issues of great concern to economists, environmental experts, and policymakers. The increased reliance on fossil fuels (oil, gas, and coal) as the main sources of energy to power economic expansion has contributed significantly to global warming and environmental degradation. However, it is on record how important energy is in the economic development process, for both developed and developing nations (Alege et al., 2018; Bhattacharya et al., 2016; Omotor, 2008; Sambo, 2008; Shahbaz et al., 2010).

Energy consumption, supply, and pricing have positive impacts on socio-economic development, living standards, and people's overall quality of life (Iwayemi, 1988; Okafor, 2012). Furthermore, as noted by Farzin and Bond (2006), the relationship between energy utilization and economic expansion is not independent of interdependence among economies and political institutions that oversee the policymaking process. Numerous empirical studies have investigated the impacts of utilization energy on CO_2 emission (Alege et al., 2018; Mesagan et al., 2018; Katircioglu&Katircioglu, 2018; Kahia et al., 2017; Bhattacharya et al., 2016; Al-Mulali et al. 2015; Apergis& Ozturk, 2015; Pao & Fu, 2013).

The outcomes of these examinations have given fascinating records of the connections between energy utilization and CO_2 emissions concerning classical Environmental Kuznets' Curve (EKC).EKC hypotheses that as per-capita income rises, environmental degradation initially rises, and then declines as income rises, resulting in an inverse U-shaped relation between per capita income to environmental pollution (Stern, 2003; Katircioglu et al., 2003; Gokmenoglu&Taspinar, 2016).

Notably, South Africa is sufficiently endowed with energy resources (coal, gas, and renewable resources) and has a relatively high rate of energy consumption. Yet, the South African economy has been unstable, particularly during the period of the political crisis in the 1980s through the early 1990s, when the country began experiencing growth following the installation of a democratic regime in 1993 (Okafor, 2012). Between 1996 and 2007, the average growth rate was 4.3 percent, and the Gross Domestic Product (GDP) aggressively increased to 400 billion U.S dollars in 2011. This subsequently declined to 295 billion U.S dollars in 2017, following the economic crisis, which led to the contraction of a wide range of sectors including manufacturing, construction, and transport.

On the other hand, South Africa has been noted as the continent's highest emitter of greenhouse gases (GHG), accounting for around 42% of all GHG emissions. In 2008, the nation was classified as the seventh-largest global GHG emitter and the thirteenth-largest emitter of fossil fuel CO2, emitting over 119 million metric tons of carbon from coal alone (International Energy Agency, 2014). This increased to 417,161 (kilotonnes), accounting for 1.16% of global CO_2 emissions. Several studies have argued that an increase in economic expansion in the period of a stable democracy is the innate cause of the increase in GHG emissions in South Africa (Menyah&Wolde-Rufael, 2010; Nasr, Gupta & Sato, 2014).

Theoretically and empirically, democracy's impact on CO_2 emissions is contentious. Some academics argued that the proper and efficient implementation of governmental policies leads to an improvement in environmental quality in democratic nations. Moreover, democracy encourages people to express their preferences, which results in pressure on the government through protests that demand environmentally sustainable initiatives (Payne, 1995; Torras& Boyce, 1998; Barrett &Graddy, 2000; Farzin& Bond, 2006; Shahbaz et al., 2013b). On the other hand, other scholars build their argument on the concept that income and democracy have a positive relationship, which is the tenet of the modernization theory. As stated in this argument, environmental quality therefore is at risk because CO_2 emissions tend to increase as income rises with the degree of democracy (see Heilbronner, 1994; Midlarsky, 1998; Scruggs, 1998; Roberts & Parks, 2007; You et al.,2015;Lv, 2017).

As this economy aims towards growth and development, interaction and integration with other economies of the world are inevitable. Therefore, among the important socio-economic factors connecting and affecting both developing and developed countries, the increasing wave of globalization has also had its divers influence on the South African economic activities. This dictates the direction of production, technology used in production, industrialization, urbanization and transportation. It has taken South African economy to a more mechanized productive system ranking as number one in the African continent (Rafindadi&Usman, 2019). This scenario has bred two-side views of the effects of globalization (Shahbaz, 2019).

There are two positions in the literature arguing that globalization could be beneficial or harmful to the society. First, Baek et al. (2009), Christmann and Taylor (2001), Lee and Min (2014), Ling et al. (2015), Panayotou (1997), Shahbaz et al. (2015), Shin (2004) and Wijen and Van Tulder (2011) argued that globalization is beneficial to the society by reducing CO_2 emissions through improved technology, thereby enhancing improved environmental quality. Globalization is also responsible for economic openness, rapid exploration of raw materials and national resources, productive activities will increase thereby increasing income, improved living conditions, such as housing, transport efficiency and better communication.

On the other hand, Baek et al. (2009), Copeland and Taylor (2004), Friedman (2005), Panayotou (1997), Shahbaz et al. (2016), Wijen and Van Tulder (2011), argued globalization could be harmful to the society since its characteristics involve urbanization which causes deforestation, and then, climate change; rapid industrialization which causes CO_2 emissions, global warming and rising sea levels; increased transportation facilities such as roads, which leads to loss of biodiversity; and economic openness also leading to massive depletion of natural resources and indiscriminate agricultural harvest for production and export consequently causing loss of vital soil ingredients (Hawken et al., 2008). All these together result in ecological imbalance and increased CO_2 emissions.

Although, globalization is adjudged to be beneficial to economies in their growth process (Shahbaz, 2019), energy consumption increases with growing economy, as a tool of economic expansion, CO_2 emission is bound to increase. Argument of opponents of globalization implies that globalization cannot ensure sustainable development because it only engenders economic activities at the expense of the future generation’s welfare since environmental quality is given away to achieve improved economic activity. Countries have become more agitated over growing pollutant activities in the economy as this has become a trade-off between increased output and conducive environment in developing countries. However, the kind of institutions that govern the process of policy making have become major determinants of pollution emitting activities in the society, this will depend on effective enforcement of environmentally friendly policies and adequate regulatory quality.

The suspected U-shaped relation amongst globalization and environmental degradation follows underlying forces of three effects of globalization on the economy (Ling, et al., 2015; Rafindadi& Usman, 2019; Shahbaz, 2019). First, through the scale effect, globalization leads to massive energy consumption through accelerated economic growth at the initial stage of globalization. Consequently, CO_2 emissions will also rise (Cole, 2006; Dedeoglu and Kaya, 2013). Second, through the composition effect, percentage of carbon-intensive inputs in operations begins to decline as structural changes begin to occur in productive activities. For example, the society attempts to shift from carbon-intensive activities, driven by huge energy consumption in agriculture, transport and service, to information-intensive activities such as replacing transportation with electronic communication (Stern, 2007).

Finally, through the technique effect, there is a total paradigm shift in production processes as part of the benefits of globalization, such that importation of knowledge and technological advancement can boost production and also help to reduce energy consumption, and thus, emissions of pollutant substances also decrease (Antweiler, et al., 2001; Jena & Grote, 2008).Therefore, the goal of this research is to examine the dynamic impacts of energy utilization, and globalization with democracy on CO_2 emissions in the subtext of EKC hypotheses in South Africa over the period of 1971 to 2014. Even though an abundance of studies on EKC have been undertaken for South Africa, incorporating Foreign direct investment, trade, financial growth, urbanization, education, population expansion, agriculture, with capita' investment, there is still a need to better understand the key role of democracy on environmental quality. This study offers several contributions to literature; first, this research incorporates the impacts of energy consumption, democracy, with globalization on the carbon dioxide emission and tests the validity of EKC hypothesis for South Africa.

Second, in order to ascertain cointegration among the series, the Bayer-Hanck multimodal cointegration test, which was invented by Bayer and Hanck (2013) is fully exploited. By combining the cointegration tests put out by Engel and Granger (1987), Johansen (1995), Boswijk (1994) and Banerjee (1998), this test of cointegration yields a consistent and reliable conclusion. As a result, the test prevents any disagreement that can occur from the findings of various cointegration tests. The robustness of the consolidated cointegration test is further tested by employing the Johansen (1995) cointegration approach.

Third, the Fully Modified Ordinary Least Squares (FM-OLS) method proposed by Phillips and Hansen (1990) is used to estimate the long-run coefficient of the variables. This method provides estimates of cointegrating regressions that are optimal and thus considers the explanatory variables' endogeneity and serial correlation effects, which emanate from the existence of a cointegrating relationship. Fourth, to determine the directional causality amongst the variables for short-run and long-run, under the structure of vector autoregressive model (VECM) Granger causality test was carried performed. Fifth, I validate results of the causality by applying innovation accounting test of forecast error variance decomposition and impulse response function (IRF).

The remaining portions of the study are organized as thus: Section 2.2 gives brief literature review. Research methodology is the main focus of Section 2.3. Finally, Sections 2.4 and 2.5, respectively, give the empirical findings as well as the conclusion and policy recommendations.

2.2 Brief Literature Review

Until recently, there have been three main strands of literature relating to energy utilization, environmental quality, and economic expansion, each utilizing different methods and tools of analysis. The first strand focuses on the relationship between environmental pollution and economic expansion, which is innate for testing the Environmental Kuznets Curve Hypotheses (Akinlo, 2009; Esso, 2010; Aboagye, 2017; Dong et al., 2017; Zakaria, 2017; Moutinho et al, 2017). The second set of studies focuses on the relation amongst energy utilization and economic expansion (Alege et al., 2018, Bhattacharya et al., 2016; Pao & Fu, 2013; Maji, 2015; Ranfindadi& Usman, 2019). The third strand of literature is a combination of the energy-environment and energy-growth relationship (Apergis& Payne, 2009; Ozturk &Acaravci, 2010; Menyah&Wolde-Rufael, 2010; Akpan & Akpan, 2012; Silva et al. 2012; Omri, 2013; Paramati et al., 2017; Zaghdoudi, 2017).

In a related vein, Shahbaz et al. (2015) utilized ARDL bounds test to analyse EKC hypothesis for Portugal over the years 1971 to 2008. The research added conventional emissions with income structure to energy use, trade liberalism and urbanism variables. The experimental findings confirmed the concept of EKC hypotheses. As in their 2010 research work, Pao and Tsai looked at the changing causal links amongst pollutant emission, energy use, with output for the BRICs nations between 1971 and 2005. The study discovered evidence in favor of the EKC using panel regression analysis, since real output displays the inverted U-shaped pattern. On other hand, Nasr et al. (2015) using co-summability approach to test if EKC for South Africa is valid by using century data (1911-2010). The outcome provides no proof to support the EKC's existence in South Africa. Moreover, Inglesi-Lots &Bohlmaann (2014) tested the existence of the EKC hypotheses in the case of South Africa using an ARDL bounds testing strategy with CO_2 emissions, energy intensity, and renewable energy for the period of 1960-2010. His empirical findings showed insufficient proof to support EKC hypotheses in South Africa. In a recent article by Adu and Elisha (2018), it was discovered that EKC hypotheses does not hold for selected countries in West Africa. In addition to evidence of EKC hypothesis found for India, Usman et al., 2019) proved the impact of democracy as a socio-political factor in the EKC is strong in the short-term but weak in the long-term.

Empirical findings documented that both roles of globalization in environmental degradation can either be positive or negative (Baek et al., 2009; Chintrakarn&Millimet, 2006; Copeland, 2005; Copeland &Taylor, 1994, 2004; Dean, 2002; Löschel et al., 2013; Lucas et al., 1992; Managi et al., 2008; Shahbaz et al., 2015, 2016, 2017; Paramati et al., 2017). According to Cole (2006) and Shahbaz et al. (2018), globalization with environmental degradation will be positively correlated if globalization experiences a positive shock that increases energy demand and spurs environmentally unfriendly activities in energy use, consequently increasing CO2 emissions. For example, this kind of relationship was established in Ahmed et al. (2016) and Shahbaz et al. (2017a) for China, Dinda (2006) for OECD and non-OECD countries, as well as the world at large, and Shahbaz et al. (2017b) for nations with high, moderate, and low incomes. Conversely, a negative shock to globalization will cause negative relations amongst globalization and CO_2 emission if such negative shock leads to a negative relation between globalization and energy demand. For instance, Lee and Min (2014) established this type of relationship in a panel analysis of both developed and developing nations, Shahbaz et al. (2013), Shahbaz et al. (2017b) and Shahbaz et al. (2017c) established this type of relationship for Turkey, China and Australia respectively, all showing globalization has a reducing impact on CO_2 emission.

Shahbaz (2019), in an investigation of this relationship among 11 emerging countries, confirmed that CO_2 emission reduces at the early stage of increasing globalization but it increases at a later stage of globalization leading to a U-shaped relation amongst globalization and carbon emissions.This type of relationship was found for Bangladesh, Iran, Philippines, South Korea and Vietnam while an inverted U- shape relationship was established for Pakistan and South Korea such that

CO_2emission rises with increasing globalization at the initial stage but it begins to decline after a turning point as globalization increases.Rafindadi and Usman (2019) have also investigated the dynamic impact of globalization and energy utilization in South Africa's environmental pollution. They showed that overwhelming fossil fuel energy utilization is responsible for South Africa’s upward EKC dynamics while globalization is a factor that helps to reduce environmental pollution in the short-term.

Given the literature reviewed, it is clear that the previous studies are concerned with how environmental degradation is affected by changes in economic variables without given a consideration to social-related variables. Therefore, this study intends to fill this research gap.

2.3 Data and Methodology

2.3.1 Data and Model Specification

Time series data for the years 1971-2014 was used for every one of the study's variables. the dependent variable which is environmental degradation, is represented by CO_2 emission’ (measured in terms of metric tonnes per capita); economic growth (*EG*) and its square are measured byGDP per capita (fixed at 2010-US Dollars), Energy consumption (EC) is measured by kilo tones per capita, democracy (DEM) is measured as per its degree with values in the range of -10 for the worst kind of dictatorship and 10 for the ideal democracy, finally, the index of globalization *(GI)* is quantified in three dimensions: economic, political and social. Economic globalization accounts for 36% of the index weight, the political dimension has 26% and the social dimension has 38% following the pioneering work of Dreher (2006). The World Development Indictors provided all of the data for the variables(2018) database, except the measure of democracy and globalization index, which are obtained from the POLITY IV dataset and the KOF Swiss Economic Institute - http://globalization.kof.ethz.ch/.

Therefore, to achieve the research objective, the general form of the environmental degradation function for this study closely follows the empirical works of Inglesi-Lotz and Bohlmann (2014); Shahbaz et al., (2013); Shahbaz et al., (2015); Aboagye (2017) with democracy and globalization incorporated as expressed in equation 2.1 below.

$$CO_{2t} = f(EG_t, EG_t^2, EC_t, DEM_t, GI_t) \quad (2.1)$$

Where CO_2 is the measure of environmental degradation, EG is the economic growth (*GDP* per capita), EG^2 is the square of economic growth (*GDP* per capita), *EC* is the energy consumption, *DEM* stands for democracy and GI measures globalization index. All the variables except DEM were transformedinto their natural logarithmic forms to provide efficient results since the log-linear specification leads to consistency.

$$\ln CO_{2t} = \alpha_0 + \alpha_1 \ln EG_t + \alpha_2 \ln EG^2{}_t + \alpha_3 \ln EC_t + \alpha_4 DEM_t + \alpha_5 \ln GI_t + \mu_t \quad (2.2)$$

Where ln is the natural logarithm and α_1 to α_5 are the long-run parameters while μ_t representing the error term assumed to have a normal distribution with zero mean. Equation 2 is estimated using the method of Fully Modified Ordinary Least Squares (FM-OLS) theorized by Phillips and Hansen (1990) to provide estimates of the best and most efficient cointegrating regressions. One benefit of this method is its ability to account for serial correlation effects and endogeneity in the explanatory variables that may arise in the explanatory variables from the presence of a cointegrating relationship.

Given that the economy of South Africa is mainly driven by agriculture, transportation, and services, we expect $\alpha_1 > 0$, $\alpha_3 > 0$ and $\alpha_2 < 0$. The expectation of the sign of democracy and globalization parameters i.e., α_4 and α_5 could be negative either or positive, depending on the role of the government and the overall impact of globalization.

2.3.2 Unit Root Tests

To determine the stationary properties of the data, both the Augmented Dickey-Fuller (ADF) and the Phillips–Perron (PP) were applied. The ADF unit root test is specified as follows:

$$\Delta y_t = \beta_t + \beta y_{t-1} + \sum_{i=1}^{p-1} \alpha_i \Delta y_{t-i} + \mu_t \ , \quad t = 1,...,T \tag{2.3}$$

where y_t is the endogenous variable; Δ is a difference operator, β_t is a deterministic term which may consist of the constant or drift and the trend, β and α are coefficients; p is the number of lags and μ_t is the residual term. The ADF and PP unit root tests are performed on each of the model's variables with null hypothesis [illegible] and $H_1 : \beta < 0$These tests are based on the t-statistic of the coefficient β, hence;

$$ADF_t = t_\beta = 0 = \frac{\beta}{SE(\beta)} \tag{2.4}$$

where β and $SE(\beta)$ are the estimated value of β and its standard error estimate respectively.

2.3.3 Bayer &HanckCointegration Test

Unlike most studies, this study explored a cointegration test theorized by Bayer &Hanck (2013) to investigate cointegration amongst the variables. This test has an impressive possibility compared to majority of literature's cointegration tests. As pointed out by Shahbaz et al. (2017) the cointegration test by Bayer &Hanck (2013) incorporates four significant cointegration test of Banerjee (1998), Johansen (1995), Boswijk (1994), Engle and Granger (1987), and produce reliable results. Therefore, if there is a discrepancy in the results, the test avoids making an arbitrary decision as to which test to apply. Furthermore, the Fisher (1932) formula is used to determine the statistical significance level for the test. The separate cointegration test's formula and P-value are as follows:

$$EG-JOH=-2[ln(Pro_{EG})+ln(Pro_{JOH})] \quad (2.5)$$

$$EG-JOH-BO-BDM=-2[ln(Pro_{EG})+ln(Pro_{JOH})+ln(Pro_{BO})+ln(Pro_{BDM})] \quad (2.6)$$

From equations (2.5) and (2.6), EG indicates the cointegration test that Engle and Granger proposed (1987) and The Johansen (1995) cointegration test is shown by JOH; their associated probability values are displayed by (Pro_{EG}) and (Pro_{JOH}), respectively. Likewise, BO is the cointegration test developed by Boswijk (1994) and BDM is the cointegration test by Banerjee (1998) with (Pro_{BO}) and (Pro_{BDM}) as the corresponding probabilities. As previously noted, we used Fisher's statistics to determine if there is cointegration amongst the investigated variables. The null hypothesis for the test is that there is no cointegration amongst all variables. It was determined that the critical values must be bigger than the estimated Fisher statistics for the null hypothesis to be rejected. If the critical value is lesser than the expected Fisher statistics, then the null hypothesis of no cointegration will not be successfully rejected. This implies a valid long-term link among the variables investigated.

2.3.4 VECM Granger Causality Test

Following the existence of cointegration (level relationship) amongst the variables in this research, the Granger causality test was performed under the framework of error correction mechanism *(ECM)*. This test has a significant advantage over the pairwise

Granger causality. Amongst these advantages arethatit allows both short- and long-run causality relationships to be estimated. However, it is only applied if there is proof that the variables are cointegrated. Therefore, framework for VECM Granger causality model can be expressed, following Ozatac et al. (2017) as:

$$\begin{bmatrix} \Delta lnCO_{2t} \\ \Delta \ln EG_t \\ \Delta \ln EG_t^2 \\ \Delta lnEC_t \\ \Delta DEM_t \\ \Delta \ln GI_{t-1} \end{bmatrix} = \begin{bmatrix} \alpha_1 \\ \alpha_2 \\ \alpha_3 \\ \alpha_4 \\ \alpha_5 \\ \alpha_6 \end{bmatrix} + \begin{bmatrix} \rho_{11i}\rho_{12i}\rho_{13i}\rho_{14i}\rho_{15i}\rho_{16i} \\ \rho_{21i}\rho_{22i}\rho_{23i}\rho_{24i}\rho_{25i}\rho_{26i} \\ \rho_{31i}\rho_{32i}\rho_{33i}\rho_{34i}\rho_{35i}\rho_{36i} \\ \rho_{41i}\rho_{42i}\rho_{43i}\rho_{44i}\rho_{45i}\rho_{46i} \\ \rho_{51i}\rho_{52i}\rho_{53i}\rho_{54i}\rho_{55i}\rho_{56i} \\ \rho_{61i}\rho_{62i}\rho_{63i}\rho_{64i}\rho_{65i}\rho_{66i} \end{bmatrix} \times \begin{bmatrix} \Delta \ln CO_{2t-1} \\ \Delta \ln EG_{t-1} \\ \Delta \ln EG_{t-1}^2 \\ \Delta lnEC_{t-1} \\ \Delta DEM_{t-1} \\ \Delta \ln GI_{t-1} \end{bmatrix} + \ldots + \begin{bmatrix} \rho_{11i}\rho_{12i}\rho_{13i}\rho_{14i}\rho_{15i}\rho_{16i} \\ \rho_{21i}\rho_{22i}\rho_{23i}\rho_{24i}\rho_{25i}\rho_{26i} \\ \rho_{31i}\rho_{32i}\rho_{33i}\rho_{34i}\rho_{35i}\rho_{36i} \\ \rho_{41i}\rho_{42i}\rho_{43i}\rho_{44i}\rho_{45i}\rho_{46i} \\ \rho_{51i}\rho_{52i}\rho_{53i}\rho_{54i}\rho_{55i}\rho_{56i} \\ \rho_{61i}\rho_{62i}\rho_{63i}\rho_{64i}\rho_{65i}\rho_{66i} \end{bmatrix}$$

$$\times \begin{bmatrix} \Delta \ln CO_{2t-1} \\ \Delta \ln EG_{t-1} \\ \Delta \ln EG_{t-1}^2 \\ \Delta lnEC_{t-1} \\ \Delta DEM_{t-1} \\ \Delta \ln GI_{t-1} \end{bmatrix} + \begin{bmatrix} \beta_1 \\ \beta_2 \\ \beta_3 \\ \beta_4 \\ \beta_5 \\ \beta_6 \end{bmatrix} ECT_{t-1} + \begin{bmatrix} \mu_{1,t} \\ \mu_{2,t} \\ \mu_{3,t} \\ \mu_{4,t} \\ \mu_{5,t} \\ \mu_{6,t} \end{bmatrix} \tag{2.7}$$

Based on equation (2.7), Δ depicts the difference operator. ECT_{t-1} is the lagged error correction term inferred from the long-run equation. $\mu_{1,t}$, $\mu_{2,t}$, $\mu_{3,t}$, $\mu_{4,t}$, $\mu_{5,t}$ and $\mu_{6,t}$ are error terms, with the assumption of zero mean and finite covariance matrices. A long-run causality relationship exists amongst the variables if the value of ECM_{t-1} is statistically significant, whereas a short-run causal relationship exists amongst the variables if the F-statistic for the first differenced variables is statistically significant.

2.4 Empirical Findings and Discussion

Table 2.1 displays the variables' descriptive statistics. The variable with the highest mean value was the square of *EG* with 76.43717, followed by *EG* with about 8.742348. The lowest mean value in the sample is CO_2 with 2.129530. Moreover, the series' standard deviation values showed that they are less volatile with the democratic variable having a standard deviation of 2.443765. This suggests that democracy tends to be more volatile among the series in the study. Additionally, the skewness values are close to zero, with CO_2, *EC*, and *DEM* having negative values and *GI*, *EG* and its squared term having positive values. The overall values of the kurtosis are positive, with the *EG* and its squared term as well as *EC* having values close to three. Given this, with Jarque-Bera normalcy test the null hypotheses cannot be rejected for any of the variables, except democracy, which is rejected at 5% level.

Table 2.1: Descriptive Statistics

Variable	lnCO2	LnEG	lnEG2	lnEC	DEM	lnGI
Mean	2.129530	8.742348	76.43717	7.790646	6.568182	3.920989
Median	2.140488	8.721759	76.06908	7.811106	7.000000	3.783150
Maximum	2.289560	8.933605	79.80930	7.976983	9.000000	4.235294
Minimum	1.935203	8.598513	73.93442	7.556413	4.000000	3.708288
Std. Dev.	0.105309	0.093432	1.639141	0.106942	2.443765	0.204227
Skewness	-0.392092	0.635467	0.653107	-0.627832	-0.039960	0.430819
Kurtosis	1.995407	2.522970	2.536410	2.530914	1.052459	1.372881
Jarque-Bera	2.977614	3.378527	3.522038	3.294007	6.965386	6.214884
Probability	0.225642	0.184656	0.171870	0.192626	0.030725	0.044715
Sum	93.69933	384.6633	3363.236	342.7884	289.0000	172.5235
Sum Sq. Dev.	0.476868	0.375371	115.5317	0.491771	256.7955	1.793471
Observations	44	44	44	44	44	44

Source: Authors' computation

Figure 2.1 demonstrates the physical attributes of the time series variables to explore the possibilities for drift, trend, seasonality, with structural breaks, the variable's time plot suggests there is no glaring indication of a trend in any of the data except the log of EG and its squared term started rising early 1990s. However, there is evidence that all the series exhibit upward and downward movements; hence, they are characterized by structural breaks at different points. These breaks are traceable to political and economic crises, such as apartheid, the global financial crisis, etc., in South Africa.

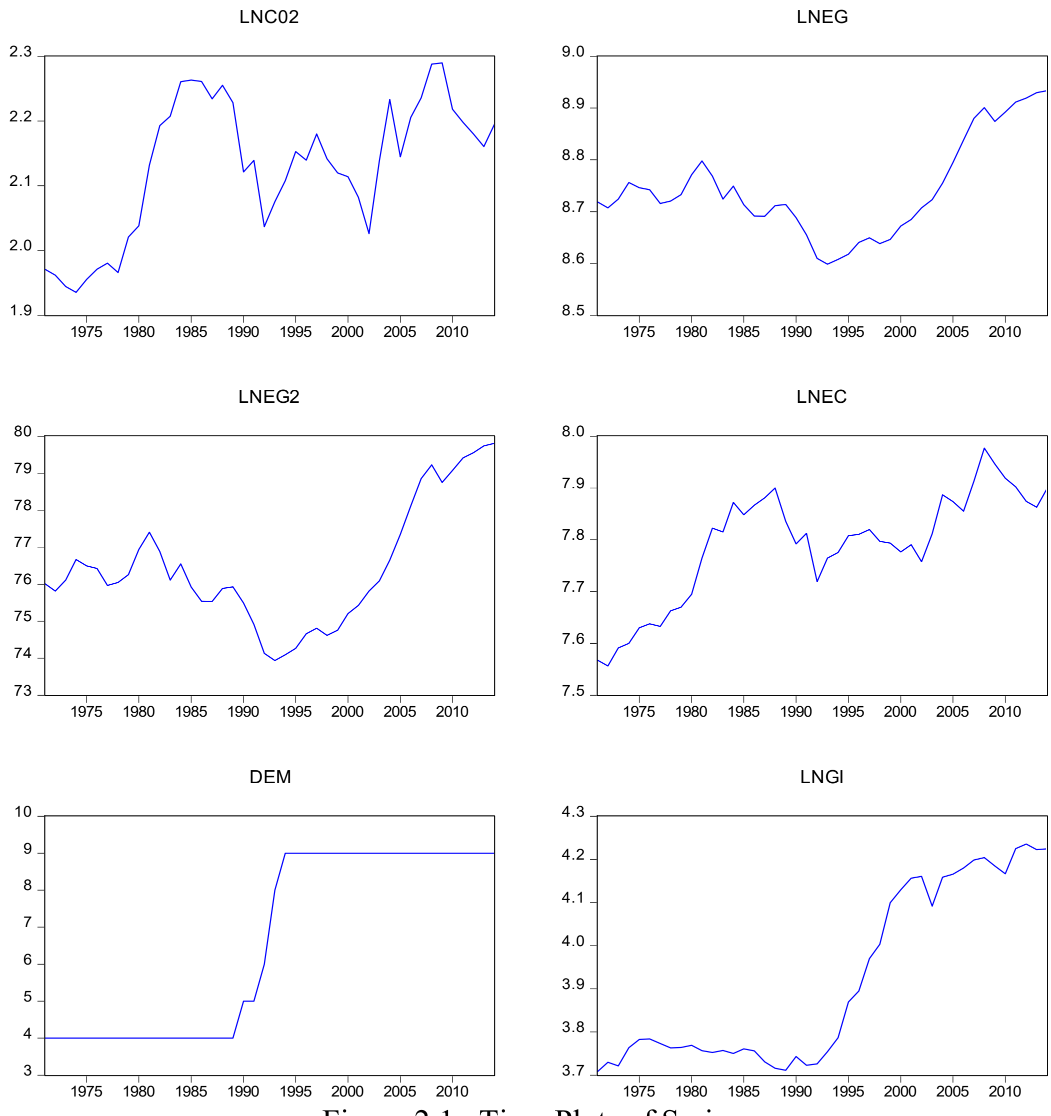
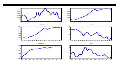
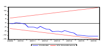
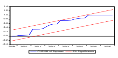


Figure 2.1: Time Plots of Series

To look into the cointegration of the variables, the integrating characteristics of the variables were examined using ADF and PP unit root. The first differences of the series are found to be stationary, indicating that the variables are integrated at the order one, 1(1).

Table2.2: ADF and PP Unit Root Tests

Variables	**Augmented Dickey-Fuller Test**		**Phillips-Perron Test**	
	Intercept	Intercept & Trend	Intercept	Intercept & Trend
	-1.8607	-1.9153	-1.9159	-2.1107
	(0.3471)	(0.6294)	(0.3221)	(0.5254)
lnEG	-0.5230	-0.9928	-0.0216	-0.6097
	(0.8764)	(0.9342)	(0.9512)	(0.9733)
$lnEG^2$	-0.5053	-0.9824	-0.0022	-0.6008
	(0.8800)	(0.9357)	(0.9531)	(0.9739)
lnEU	-1.9332	-2.0063	-1.9331	-2.0575
	(0.3145)	(0.5814)	(0.3145)	(0.5540)
DEM	-1.0481	-2.0165	-0.8267	-1.7218
	(0.7271)	(0.5756)	(0.8013)	(0.7242)
lnGI	-0.0885	-1.3288	-0.2487	-1.5964
	(0.9612)	(0.8671)	(0.9287)	(0.7780)
$\Delta lnCO_2$	-6.2228^{***}	-6.1997^{***}	-6.2259^{***}	-6.2009^{***}
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
	-4.1213^{***}	-4.2694^{***}	-4.1391^{***}	-4.1556^{***}
	(0.0024)	(0.0082)	(0.0023)	(0.0110)
	-4.1266^{***}	-4.2789^{***}	-4.1435^{***}	-4.1652^{***}
	(0.0024)	(0.0080)	(0.0023)	(0.0107)
$\Delta lnEU$	-6.2420^{***}	-6.3226^{***}	-6.2439^{***}	-6.3236^{***}
	(0.0000)	(0.0000)	(0.0000)	(0.0000)
DEM	-3.4976^{**}	-3.4557^{*}	-3.4488^{**}	-3.4039^{*}
	(0.0129)	(0.0577)	(0.0146)	(0.0645)
$\Delta lnGI$	-5.3429^{***}	-5.3656^{***}	-5.4697^{***}	-5.4821^{***}
	(0.0001)	(0.0004)	(0.0000)	(0.0003)

Notes: ***, **, and * denote significance level at 1%, 5%, and 10%. Values in parentheses are probabilities

Therefore, we test for the existence of cointegration amongst the variables using the Bayer and Hanck cointegration procedure. Based on the results presented in Tables 2.3 and 2.4, using the lag length 2, it was found that the statistics for all four combined cointegration tests are greater than the critical values in the six equations, indicating 6 cointegrating vectors. The implication of this result is that for the years 1971-2014, the variables exhibit a valid long-run relationship. The robustness of the Bayer and Hanck (2013) cointegration technique is tested employing the Johansen cointegration approach. The findings indicate there is presence of cointegration as Trace Statistic confirms with 4 cointegrating equations and Maximum Eigen Value confirms with 2 cointegrating equations.

Table 2.3 : Panel A: The Results of Bayer and Hanck's Cointegration Test

Model Estimated	**EG–JOH**	**EG–JOH–BO–BDM**	**Co-integration**
$\ln CO_{2t} = f(\ln\text{EG}_t, \ln\text{EG}_t^2, \ln\text{EC}_t, \text{DEM}_t, \ln\text{GI})$	14.37***	47.99***	Yes
$\ln\text{EG}_t = f(\ln CO_{2t}, \ln\text{EG}_t^2, \ln\text{EC}_t, \text{DEM}_t, \ln\text{GI})$	13.91***	47.16***	Yes
$\ln\text{EG}_t^2 = f(\ln\text{EG}_t, \ln CO_{2t}, \ln\text{EC}_t, \text{DEM}_t, \ln\text{GI})$	13.89***	47.15***	Yes
$\ln\text{EC}_t = f(\ln\text{EG}_t^2, \ln\text{EG}_t, \ln CO_{2t}, \text{DEM}_t, \ln\text{GI})$	15.29***	125.81***	Yes
$\text{DEM}_t = f(\ln\text{EC}_t, \ln\text{EG}_t^2, \ln\text{EG}_t, \ln CO_{2t}, \ln\text{GI})$	14.95***	31.99***	Yes
$\text{DEM}_t = f(\text{DEM}_t, \ln\text{EC}_t, \ln\text{EG}_t^2, \ln\text{EG}_t, \ln CO_{2t})$	15.52***	32.18***	Yes

Notes: *** denotes level of significance at 1%. Critical value of 1% level is 10.419 for EG–JOH and 19.888 for EG–JOH–BO–BDM. K = 5. Selected lag length is 2.

Table 2.4: Results of Johansen Cointegration Test

Hypothesis	Trace Statistic	Maximum Eigen Value
None	150.00***	52.36***
At most 1	97.65***	38.69**
At most 2	58.96***	27.11
At most 3	31.85**	16.42
At most 4	15.42	12.22
At most 5	3.202	3.202

Note: *** and ** shows significance at 1%, and 5% levels of significance respectively. The selected lag length is 2.

Table 2.5 reports the long-run FMOLS estimation results based on equation 2. In-line with the EKC hypotheses, the coefficients of economic growth (*EG)* and its square (EG^2) are, respectively positive and negative, reflecting an inverted-U-shape in the relationship of economic growth with environmental degradation. Furthermore, environmental degradation is more elastic to economic growth at lower levels of income than at higher levels of income. Specifically, this result implies that a 1% positive shift in economic growth causes a long-run increase in environmental degradation by 20.35%.

This finding implies that at the early stage of economic development, South Africa experiences a rising trend in emissions of CO_2 known as the scale effect where production activities are characterized by a high level of CO_2 emissions with less stringent environmental policies. However, after economic growth reached its turning point, emissions of CO_2begins to decrease. This result aligns with the evidence in favour of the EKC hypothesis by Pao and Tsai (2010) for the BRIC countries, Shahbaz et al., (2013a) for South Africa and Shahbaz et al. (2015) for Portugal.

Table 2.5: Long-Run FMOLS Coefficients

Dependent variable = $\ln CO_2$ Emissions				
Variable	**Coefficient**	**Standard Error**	**T-statistic**	**P-value**
Constant	-95.41*	47.46	-2.010	0.051
$lnEG$	20.35*	10.82	1.880	0.068
$lnEG^2$	-1.159*	0.615	-1.885	0.067
$lnEC$	1.124***	0.043	26.33	0.000
DEM	0.002	0.006	0.302	0.764
$lnGI$	0.144*	0.075	-1.901	0.064
R-squared	0.943	Mean dependent variables		2.133
Adjusted R-squared	0.936	S.D. dependent variable		0.104
S.E. of regression	0.026	Sum Squared Residuals		0.026
Long-run variance	0.001			

Note: *** and * denote Significance at 1% and 10% levels.

The finding also echoes the major discovery made by Usman et al. in 2019 in support of the EKC hypothesis in the context of Indian democracy. More so, the result found in support of the EKC hypothesis is not consistent with Choi et al. (2010), Jebliand Youssef (2015) and Nasr et al. (2015) who found U-shaped-relations amongst economic growth and CO_2 emissions in Japan, China, Tunisia, South Africa, Nigeria, Senegal, and Cameroon. Apergis et al. (2018) submitted that Environmental degradation is put under strain in Africa sub-Saharan countries by economic growth.

The empirical result further demonstrates that the correlation amongst energy utilization and CO_2 emissions with a measure of environmental degradation is positive, elastic, and statistically significant at the 1% level. This implies a 1% increase in energy consumption increases CO_2 emission by 1.124% in the long term. These results are consistent with Inglesi-Lots and Bohlmaann (2014), Nasr et al. (2015), Ahmed et al. (2016) and Rafindadi and Usman (2019) who reported that as energy consumption increases, CO_2 emissions would increase. Similarly, our finding is aligned with Hu et al. (2018) who discovered that the utilization of main energy sources like fuel oil, natural gas, and coal in the production process triggers CO_2 emissions by 1.2798, 0.6250, and 0.4498 t/t.

The result based on the coefficient of democracy shows that the democratic regime in South Africa positively but insignificantly impacts CO_2 emissions. This result, therefore, confirms the modernization theory that as income rises with the increasing degree of democracy, carbon dioxide emissions will increase too. Moreover, our result deviates from Lv (2017) who found that democracy reduces CO_2 emissions once a country has achieved a certain income level. Shahbaz et al. (2013b) documented that democracy in Romania promotes environmental quality improvement through the stringent implementation of environmental policies by the government, while Usman et al. (2019) revealed that even though the sign of democracy is negative on environmental degradation in India, it is only significant in the long- run.

Table 2.6 reports estimates of the causality test for both long-run and short-run. Based on the long-run result, a one-directional causal relationship runs from economic expansion, square of economic growth, energy consumption, democracy, and globalization to environmental degradation measured by CO_2 emissions. More so, I found the existence of a unidirectional causal relationship running from

CO_2emission, economic growth' squared economic growth, and democracy, with globalization to energy utilization in the long-run. Implication for these results is that changes observed in economic expansion and its squared term, energy utilization, democracy with globalization adequately predict changes in CO_2 emissions. Similarly, changes in CO_2 emissions, economic growth, squared economic growth, democracy, and globalization also predict changes in economic consumption in the long-term for South Africa. These results reflect the finding by Chandia et al. (2018), in which one-way causality occurs between economic performances with population to CO_2 emission for Pakistan. It also agrees with Ranfindadi (2016); Ranfindadi and Usman (2019). In the short-term, unidirectional causation was observed from globalization to CO_2 emission, energy utilization to CO_2 emission, with globalization to energy utilization. Additionally, it was found that, in causality sense, economic growth and its squared term Granger-cause democracy, which concurs with the theory of modernization. This finding corroborates the major finding in Usman et al. (2019). Finally, our results suggest that democracy causes CO_2 emissions. This could be traceable to the role played by income as revealed carefully in Alhassan and Alade (2017) who tested the relationship between income and democracy in Africa and confirmed that increasing the degree of democracy leads to an expansion in the income of the population.

Table 2.6: Causality Test Results

	Short-run Causality						Long-run
Dependent variable	$\ln C0_{2t-1}$	$lnEG_{t-1}$	$lnEG^2_{t-1}$	$lnEC_{t-1}$	DEM_{t-1}	$\ln EGI_{t-1}$	ECM_{t-1}
$lnCO_{2t}$	–	1.056 (0.589)	1.079 (0.583)	7.582** (0.023)	5.389* (0.068)	4.807* (0.090)	-0.530** [-2.382]
$\ln EG_t$	0.673 (0.714)	–	0.666 (0.717)	0.328 (0.849)	0.231 (0.891)	0.431 (0.806)	–
$lnEG_t^2$	0.673 (0.714)	0.683 (0.711)	–	0.354 (0.838)	0.231 (0.891)	0.425 (0.809)	–
$lnEC_t$	0.665 (0.717)	0.904 (0.637)	0.927 (0.629)	–	3.022 (0.221)	5.501* (0.064)	0.586** [-2.028]
DEM_t	0.603 (0.739)	6.863** (0.032)	6.834** (0.033)	2.644 (0.267)	–	1.106 (0.575)	–
$\ln GI$	0.5302 (0.767)	3.232 (0.199)	3.247 (0.197)	0.022 (0.989)	2.972 (0.226)	–	–

Notes: The p-values are given in parenthesis ( ) and T-Statistic [ ]. ** and * denote rejection of the null hypothesis at 5% and 10% levels. The lag length selected is 2.

Furthermore, exploring the technique of innovation accounting, our results affirm the causality test. Specifically, the results of forecast error variance decomposition (FEVD) in Table 2.7 divulge, which is based on the 10 horizons, indicates that CO_2 emissions is explained by 78.99% of its own innovative shocks. Also, economic expansion, square of economic expansion, energy consumption, democracy with globalization account for 7.01%, 3.79%, 0.45%, 7.14% and 2.81% to CO_2 emissions. The results further show that the economic growth and its squared term are explained mainly by their innovative shocks which account for 89.38% and 89.67% respectively. This is followed by energy consumption, which explains about 6.38% and 6.22%. It is also observed that CO_2 emissions are the major contributor to energy consumption and democracy with about 72.97% and 42.21% respectively. These contributions are even higher than own innovative shocks, which are as low as 4.43% in the case of energy consumption and 31.41% for democracy. Even though the own shocks of globalization are 25.48%, the contribution of CO_2 emissions is ranked second with about 9.29%.

Table 2.7: Variance Decompositions

Period	S.E.	LNC02	LNEG	LNEG2	LNEC	DEM	LNGI
Variance Decomposition of LNC02:							
1	0.049971	100.0000	0.000000	0.000000	0.000000	0.000000	0.000000
2	0.079479	84.13983	2.892006	1.848537	0.363645	8.397269	2.358708
3	0.101137	81.59993	4.684659	2.690497	0.243808	8.639381	2.141726
4	0.121072	79.96206	5.254407	3.715170	0.230125	8.176939	2.661297
5	0.136725	79.75356	5.594535	3.824122	0.258128	7.971440	2.598211
6	0.150632	79.31938	5.923594	3.965623	0.300814	7.882141	2.608444
7	0.164119	79.16834	6.219248	3.942157	0.336890	7.659542	2.673827
8	0.176712	78.98630	6.528251	3.873191	0.380197	7.500097	2.731960
9	0.188514	78.86258	6.795991	3.829479	0.419814	7.322246	2.769888
10	0.199804	78.79430	7.011198	3.791439	0.448396	7.141686	2.812987
Variance Decomposition of LNEG:							
1	0.024877	5.471835	94.52816	0.000000	0.000000	0.000000	0.000000
2	0.044757	3.890799	94.23984	0.401440	1.278660	0.114583	0.074675

3	0.060802	4.293092	92.24273	0.806141	2.095373	0.503036	0.059632
4	0.072652	4.117655	91.91646	0.814221	2.460660	0.638838	0.052164
5	0.082002	4.016449	91.27022	0.695946	3.251130	0.695948	0.070310
6	0.090138	3.922195	90.68070	0.604293	4.045747	0.654866	0.092196
7	0.097264	3.670788	90.34819	0.539878	4.696247	0.586806	0.158096
8	0.103583	3.464596	89.98039	0.480022	5.343399	0.527530	0.204064
9	0.109346	3.307447	89.63240	0.432478	5.916725	0.476042	0.234903
10	0.114653	3.136444	89.38147	0.394142	6.380691	0.433264	0.273990
Variance Decomposition of LNEG2:							
1	0.435413	5.388842	94.60669	0.004470	0.000000	0.000000	0.000000
2	0.783269	3.801759	94.37385	0.353649	1.278889	0.117466	0.074385
3	1.064094	4.171194	92.42279	0.752572	2.084837	0.510202	0.058404
4	1.271740	3.985003	92.11591	0.765905	2.432858	0.648834	0.051489
5	1.435732	3.883893	91.48350	0.654206	3.200529	0.709250	0.068617
6	1.578526	3.792807	90.90996	0.567666	3.970503	0.670044	0.089021
7	1.703701	3.547017	90.59317	0.506944	4.597536	0.602599	0.152731
8	1.814756	3.346310	90.24046	0.450386	5.222621	0.543434	0.196786
9	1.916114	3.194008	89.90720	0.405547	5.775845	0.491319	0.226082
10	2.009506	3.027856	89.66953	0.369418	6.222173	0.447445	0.263574
Variance Decomposition of LNEC:							
1	0.035679	76.05828	1.602015	0.646445	21.69326	0.000000	0.000000
2	0.056587	73.57453	2.333796	4.560167	10.37994	5.122490	4.029080
3	0.075046	74.20803	4.853531	5.035199	6.624258	4.894313	4.384668
4	0.087339	72.44883	6.271156	5.938376	6.438709	4.986567	3.916365
5	0.098134	72.87893	6.314102	6.706665	5.638248	4.690629	3.771424
6	0.108783	73.16192	6.569953	6.735259	5.092858	4.632350	3.807662
7	0.117547	72.93211	6.986559	6.734488	4.969952	4.745226	3.631669
8	0.126158	72.92082	7.105610	6.925734	4.728342	4.697752	3.621740
9	0.134550	73.03466	7.199210	6.947524	4.521098	4.655683	3.641821
10	0.141992	72.97291	7.343710	6.985272	4.434244	4.678553	3.585310
Variance Decomposition of DEM:							
1	0.316199	16.17856	2.729513	0.855077	5.676151	74.56070	0.000000
2	0.616292	21.09690	5.395386	7.411847	9.196860	56.40395	0.495052
3	0.868982	26.72865	9.649123	9.771983	6.341240	47.12871	0.380293
4	1.129688	32.50664	13.99056	9.385711	4.311711	39.57846	0.226919
5	1.345311	35.33916	16.42968	8.765125	3.218913	36.02781	0.219317
6	1.520413	37.56542	17.25795	7.941984	2.520357	34.43500	0.279298
7	1.665637	39.30206	17.53389	7.330974	2.136504	33.29927	0.397295
8	1.782092	40.37719	17.60886	6.923129	1.956595	32.51587	0.618356
9	1.880552	41.33439	17.44875	6.554842	1.913854	31.92369	0.824480
10	1.966323	42.20951	17.18006	6.249849	1.936906	31.41142	1.012254
Variance Decomposition of LNGI:							
1	0.027464	7.821788	0.907866	0.305629	20.39533	2.596940	67.97244
2	0.041279	4.375533	2.574296	5.348947	37.04355	1.162082	49.49560
3	0.056646	3.057126	2.270644	3.521468	46.08209	1.733987	43.33468
4	0.072711	4.302236	1.385341	4.018077	47.52093	3.676518	39.09690
5	0.088892	4.744974	1.496257	5.610421	48.40743	4.866521	34.87440
6	0.105322	5.499940	2.313364	6.682523	47.75937	6.208693	31.53611

7	0.121765	6.820360	3.280761	7.291925	45.84515	7.281087	29.48072
8	0.137232	7.836160	4.283119	7.802669	44.26914	8.063486	27.74542
9	0.151383	8.576318	5.134290	8.085567	43.05395	8.731285	26.41859
10	0.164485	9.292115	5.806071	8.267094	41.88984	9.260583	25.48430

Finally, the impulse response function (IRF) to analyze the CO_2 emissions function was applied. The results, therefore, validate the findings of the causality based on VECM. Particularly, the result of the IRF shows the rebuttal of CO_2 emission to own shock is positive throughoutthehorizon. Even more, CO_2 emissions respond positively to changes in economic expansion, square of economic expansion, energy utilization, with democracy, while it responds negatively to globalization. Furthermore, the responses of energy utilization to CO_2 emissions, economic expansion, and square of economic expansion with democracy are positive while to globalization is negative. Another interesting discovery of our finding is that the responses of energy utilization and CO_2 emission to economic growth are positive; indicating that the shock in economic growth increases these variables while initially increasing globalization up to the 4th year and then begins to decrease globalization.

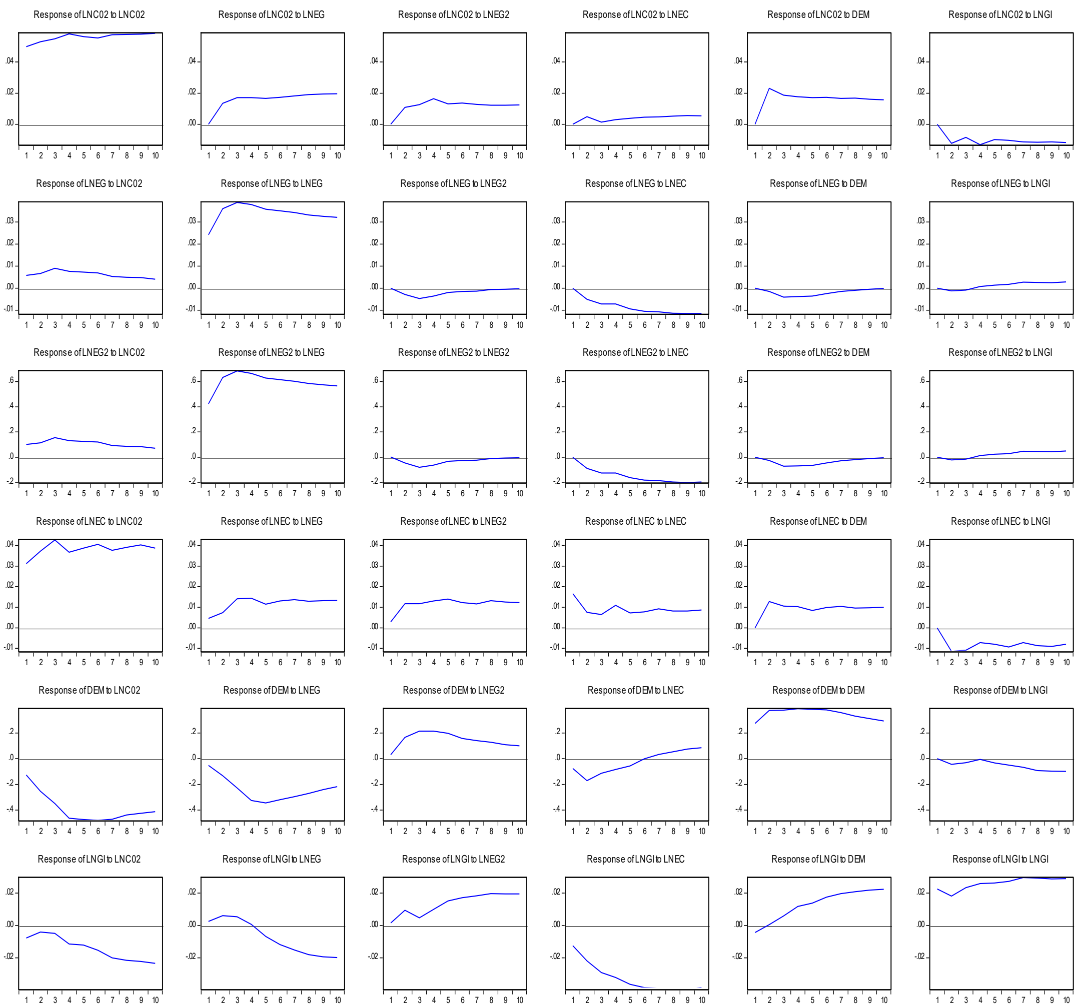


Figure 2.2:Response to Cholesky One S.D. (d.f.Adjusted) Innovations

2.5 Conclusion and Policy Recommendations

The goal of the study is just to examine impacts of energy utilization, democracy, also globalization on environmental degradation that is measured by CO_2 emission in the perspective of EKC hypotheses for South Africa between the years 1971 and 2014. I used the current test of cointegration developed by Bayer &Hanck (2013), which confirmed the long-run relations amongst the variables. Then long-run and short-run coefficients were approximated based on FM-OLS estimator. The results showed that economic expansion has a statistically significant positive impact on CO2 emission, while its inverted-U-shape. This lends support to the EKC hypothesis in South Africa. In addition, our result divulged that, while energy consumption positively increases with CO_2 emission, the impact of democracy is positively insignificant, indicating that as the degree of democracy square term has a negative impact, confirming that the economic growth-CO_2emissions relationship for South Africa is patterned towards an increases, CO_2 emissions would rise through the increase in income as carefully argued by advocates of modernization theory. The result further suggests that as the pace of globalization increases, CO_2 emissions are found to dampen due to technologies and technical know-how associated with globalization.

Furthermore, the result of the Granger causality under the VECM suggested a one-way long-run causality, running from economic' expansion, square of economic' expansion, energy utilization, democracy, with globalization to CO_2 emission. Moreover, long-run causal relation is also found running from CO_2 emission, economic expansion, and square of economic expansion, democracy, also globalization to energy Usage. In the short run, causal relations are found running from globalization to CO_2 emission, energy consumption to CO_2 emissions, also globalization to energy utilization. In addition, economic expansion and its squared term are said to Granger cause democracy, while democracy Granger causes CO_2 emission. These results are further affirmed by findings based on the innovation accounting tests.

Therefore, based on these findings, we recommend that policymakers and stakeholders should pay adroit attention to reducing environmental degradation caused mainly by the use of fuel oil and other traditional pattern of energy utilization. Specifically, the government of South Africa should impose taxes on carbon emissions, which is the surest way to reduce CO_2 emissions in countries with less stringent environmental laws. These taxes should be implemented in a manner that firms and industries will not shift production base from the country.In addition, to accelerate growth, government should promote and stimulate democracy since causality runs from democracy to economic growth. Furthermore, policies that strengthen globalization should be pursued vigorously to accelerate growth and technological and technical know-how required to transform the economy into an industrialized one. Finally, emphasis of energy policy should be placed on the need to promote clean energy–renewables like wind and wave, solar, hydropower, etc.–becausethese kinds of energy generate lower levels of CO_2 emissions.

Chapter 3

TESTING THE ENVIRONMENTAL KUZNETS CURVE WITH STRUCTURAL BREAKS: THE ROLE OF GLOBALIZATION, ENERGY USE, AND REGULATORY QUALITY IN SOUTH AFRICA

3.1 Introduction

Globalization has developed into an important feature of the 21st century's economic development of African nations. Without this, Africa would maintain a slower pace of growth and development compared to the remainder of the world. The rising pace of globalization has been said to facilitate infrastructural and industrial growth, as well as increased economic activity which results in increased energy use, and consequently, causes environmental degradation (See Dreher, 2006; Rafindadi& Usman, 2019; Rodrik, 2008; Usman et al., 2020a&b; Alhasssan et al. 2020). As much as this might be of great benefit to the developing South African economy, it also has its attendant downsides, one of which is environmental damage. This, therefore, poses the challenge of seeking effective management of the tool of globalization. On one hand, this might require the formulation of effective regulatory policies that check and ensure that the society meets expected environmental standards despite imbibing new culture and technology. On the other hand, it might require the formulation of regulatory policies that utilize the positive sides of globalization as a tool for overcoming environmental challenges. This paper intends to find out the roles of both regulatory quality and globalization in environmental pollution in South Africa.

Two distinct types of hypotheses; the Pollution Haven hypotheses and the Halo hypotheses have been used to explain how globalization and environmental degradation are linked (Asghari, 2013; He, 2006; Hoffmann et al., 2005; Taylor, 2005; Cole, 2004; Harrison &Eskeland, 1997). In one perspective, the Pollution haven hypotheses contend that industries want to locate and run in regions with laxer environmental restrictions. This explains why multinational companies seek to locate their high pollutant factories in developing countries where there are weak regulations regarding environmental pollution so as to avoid the cost of breaking such rules in more advanced countries with more stringent rules.

Developing countries are characterized by weak institutions since regulatory quality is a product of these institutions (Acemogluet al.,2003). It is presumed that the regulatory quality in developing countries may or may not have a direct impact on environmental degradation in an African country. They are also characterized by bureaucratic bottlenecks corruption and political instability, which reduces their power to ensure stringent laws (Fredriksson &Svensson, 2003; Galinato& Chouinard, 2018). Meanwhile, as developing countries, a typical African country is often vulnerable to the developed countries' policies and subject to the international conditions given by foreign investors (Hubbard & O'Brien, 2013; Galinato& Chouinard, 2018).

As various governments seek to entice foreign direct investment, they are tempted to invite foreign private partnerships in the development of their environmental policy. If foreign investors are involved in policy formulation, they tend to design laws that align with models of their firms (Cole et al., 2006). Therefore, the multinational firms may find the African environment as a haven for their high pollutant industries because policymakers may be slack in their environmental regulatory rules and lower their standards in order to continue attracting foreign investments.

The Pollution Halo hypothesis on the other hand argues that environmental pollution reduction technology will be transferred from one country to another along with the establishment of foreign and multinational institutions in the benefitting countries. The institutions developed to international standards will take on the responsibility of ensuring a safer environment. This school of thought believes that globalization promotes better environmental standards through information, research, and innovations that are globally exchanged and help to decline the effect of greenhouse-gases and CO_2 emissions. Research and innovations aid the development of technology for cleaner energy and a new production process that substitutes less energy-intensive inputs for more energy-intensive inputs. The information has provided awareness about climate change and the need for a greener environment. It has also aided the transfer of environmentally friendly culture across the world. More importantly, institutions are better structured to ensure compliance with rules and regulations. The level of technology also matters in the level of compliance with regulations (Acemoglu et al., 2002). With insufficient technology in the developing states, ensuring full environmental regulations may just be a fairy-tale because they have to compromise environmental standards to meet production. This explains why through the Halo effects, an African developing country is expected to benefit fromthe transfer of foreign ideas as this transfer green technology for environmental monitoring into their countries.

According to the concept of the environmental Kuznets' Curve (EKC) advanced by Grossman & Krueger (1991, 1995, 1996), at the early stage of development, a less developed country tends to prioritize economic growth at the expense of a green environment until they make further progress in development and become conscious of environmental damages, and then, begin to seek solutions. Pollution is high at the initial stage because of the exploration of natural resources and massive production through the primary sector. Globalization facilitates the structural changes in the growth and development process. Economic growth activities including foreign direct investment (Acharyya, 2009; Shahbaz et al., 2015; Bokpin, 2017), energy consumption (Soytas et al., 2007; Zhang & Cheng, 2009; Bekun et al., 2019), transportation (Rondinelli& Berry, 2000; Hill, 2009; Black, 2010), international trade (Grossman & Krueger, 1991; Dean, 1992; Lopez, 1994;Cole, 2004; Copeland, 2013; Iorember et al., 2020a&b;), mining and agriculture (Dudka& Adriano, 1997; Trébuil, 1995; Woods, 2004; Olanipekun et al., 2019) and tourism (Katircioglu, 2014; Raza, Sharif, Wong & Karim, 2017; Usman et al., 2020c) well proven in the literature to cause environmental degradation to form the link amongst globalization and environmental- degradation (see also Grossman & Krueger, 1995; Stern et al., 1996; Halicioglu, 2009).This is because the promotion of these requires the exchange and development of technology which constantly intermingles with human activities that damage the environment, these breed urbanization, deforestation, indiscriminate farming, air pollution, sea pollution, etc.(Nentjes et al., 2007; Huwart&Verdier, (2013). As they make progress, with better technology in production practices, environmental pollution can be reduced. Industries grow and structural change fromindustry to service sector alleviates environmental pollution while improved technology also reduces the effect of urban pollution (Nentjes et al., 2007).

Therefore, as globalization induces economic activities, they have a direct positive and negative impact on environmental quality. Thus, environmental- degradation rises at an early stage and then begins to fall as income increases. This is the concept of Environmental Kuznets Curve (EKC) hypothesis (Stern, 2004; Soytas et al., 2007).

Thus, effects of globalization could be either negative or positive depending on the net shocks to globalisation (Rafindadi& Usman, 2019; Usman et al., 2020a).To maximize the positive use of globalization without jeopardizing environmental quality, good regulatory quality is a necessary tool. Pollution control has become a contemporary energy issue confronting policymaking. This involves issuing of emission license, carbon tax where necessary, and carbon emission quota above which violators will be fined and regulation of resource exploration margins. Developing countries are not left behind even though many of them do not have adequate means to fight this. Apart from corruption and weak rule of law, poverty makes the citizens helpless and cannot but violate environmental standards for survival (Olanipekun et al., 2019).

The link between environmental quality, globalization, with regulatory quality is of interest in South Africa considering their leading position in CO_2 emissions in Africa and their giant strides to develop among other African countries which suggests massive use of energy. Thus, this study intends to empirically confirm the status of the relationship between environmental degradation and the dualfactorof globalization and regulatory quality while accounting for economic growth and energy utilization in South Africa. Objectively, the roles of regulatory quality, and globalization in the conventional EKC in South Africa were assessed. This isimportant at this stage because globalization is rapidly helping the desires of many developing nations for sustained economic growth, but environmental pollution has become a global problem, which is being buttressed by globalization.

Therefore, as economies are seeking to strike a balance between this good and bad, the study helps us understand the role of regulations in this mission to reduce global warming. This will enable policymakers to develop an effective institutional framework that ensures effective regulatory quality. With this knowledge, Africa can also review their priority policy rules and utilize globalization for the benefit of the environment by reducing the impact of human activities, which damages the environment in the quest for economic growth and development.

The remainder of the research is structured as thus: Section 2 is a review of literature; Section 3 is a description of the methodology used, Section 4 presents the analysis of results whilst Section 5 is the conclusion.

3.2 Review of Related Literature

3.2.1 Globalization and Environmental Degradation

There has been an enormous volume of research pointing attention to the benefits and demerits of globalization to the environment, few of these have been documented for Africa. Shahbaz et al. (2016) assessed the panel of 19 African countries and find that globalization has a decreasing effect on environmental degradation, but individual country analysis shows different effects of globalization on their environment. Rafindadi& Usman (2019), for South Africa, establish that globalization leads to a substantial decrease in environmental degradation caused by an expansion in energy use.

Beyond Africa, Shahbaz et al. (2017a) indicate that as economic growth causes environmental pollution in China, globalization decreases pollution; while in Italy, Saint et al., (2019) find that increase in energy utilization increases CO_2 emission, but an increase in globalization index reduces it. In India, Shahbaz et al., (2015) empirically confirm that globalization hinders the improvement of environmental quality by increasing CO_2 emission as the globalization process increases while Usman et al. (2020b) found that the level of globalization in the United State hurts the environment measured by the per capita ecological footprint.

Liu et al. (2020) establish an inverted-U-shaped, relationshipbetween globalization and CO_2 emission for G7 countries; Shahbaz et al. (2019) also establish an inverted-U-shaped between globalization and environmental degradation for 16 out of 87 countries, these are within middle- and high-income group of countries thereby suggesting globalization initially causes environmental damage but as it increases, it becomes an advantage in the contest against environmental degradation. These suggest that embracing globalization will decrease environmental degradation in the future. In Shahbaz et al. (2019), the U-shaped relationship applies to7countries while neither U- nor inverted-U-shaped relations occur in 64 countries. Panayotou (2000) found that there are both positive and negative impacts of globalization on the environment, this is dependent on how the diverse channels of economic globalization which include investment, technology, trade, and finance are being managed to promote green environmental culture.

3.2.2 Regulatory Quality and Environmental Degradation

On the effectiveness of regulations in the quest for a greener environment, few studies have empirically established the link between regulations and environmental quality. Samimi et al. (2012) combines 21 of Middle East and North Africa (MENA) nations for the years 2002 to 2007 using the annual data where regulatory quality is specified as one of the indicators of good governance. Their results show that environmental quality improves with better government effectiveness and regulatory quality because the indicators observed has negative impacts on environmental degradation. Nonetheless, Abid (2016) found that government effectiveness and corruption control have a reducing effect on environmental degradation in Sub Sahara Africa but regulatory quality and rule of law do not. Adedoyin et al. (2020) use panel data from the five BRICS countries between 1990 and 2014. They show coal utilization has a significant positive impact on CO_2 emission, but regulations through regulatory quality index with the interaction of coal rents and the cost of damage do not reduce CO_2 emissions. In Galinato and Chouinard (2018), there is no evidence that environmental regulations from a neighboring country could influence environmental regulations in one country but they establish that higher institutional quality leads to more stringent environmental regulations.

3.2.3 Energy Consumption and Environmental Degradation

There has been an enormous volume of research pointing attention to energy utilization and environmental degradation. For example, Haggar et al. (2012) highlight relevance of causal links amongst energy utilization, economic expansion, and environmental degradation (pollution). The insights of such causal relations obviously affect nations' mitigation strategies regarding GHGs emission and as such determine their climate policy agenda. Similarly, Dogan and Turkekul (2016) find that the relation amongst energy utilization and CO_2 emission is positive and significant in the USA. This is confirmed by the recent papers such as Usman et al. (2019) who document that energy utilization exerts beneficial impact on environmental degradation in India.

Rafindadiand Usman (2019) also find that the level of environmental pollution in South Africa is dependent on the level of energy consumption. Ike et al. (2020a) find that energy utilization is linked to CO_2 emission from heterogeneous sources. Other studies that document similar findings include Apergisand Payne (2009a&b; 2010); Al-Mulali et al. (2015); Apergis and Ozturk, (2015); Gokmenoglu and Taspinar, 2016; Bhattacharya et al. (2016); Kahia et al. (2017); Alege et al. (2018); Mesagan et al. (2018), KatirciogluandKatircioglu (2018); Ibrahim and Alola (2020).

Given the review of literature related to this study, it can be deduced that most studies conducted to examine the determinants of environmental degradation in South Africa have failed to capture the effect of structural breaks. Of course, there is likelihood that these breaks can affect the behaviours of environmental degradation variable. Therefore, this study is not only testing the validity of the EKC for South Africa but also capturing the effects of structural breaks in determining the behaviours of environmental quality.

3.3 Methodology and Data Description

3.3.1 Econometric Modelling via ARDL Bound Testing Approach

Environmental degradation measured by ecological footprint was modeled as a function of regulatory quality, energy use, globalization, and economic expansion in

South Africa using a quarterly frequency series from 1996:Q1 to 2016:Q4. We specify the equation as follows:

$$EFP = f(GDP, GDP^2, EU, GLO, RQ) \quad (3.1)$$

Where the dependent variables denote ecological footprint, regressed on arrays of independent variables, which include economic growth and the square term measured by real gross domestic product (GDP), energy utilization, globalization index and regulatory quality. The variables in Equation (2.1) except regulatory quality were converted into natural logarithms to help stabilize variance and interpret the estimation in elasticities as shown below:

$$\text{lnEFP}_t = \alpha_0 + \beta_1 \text{lnGDP}_t + \beta_2 \text{lnGDP}_t^2 + \beta_3 \text{lnEU}_t + \beta_4 \text{lnGLO}_t + \beta_5 \text{RQ}_t + \varepsilon_t \quad (3.2)$$

Where ln represent natural logarithms and ε_t is the error term, which is a white noise process with varianceσ^2, $\varepsilon_t \sim iid(0, \sigma^2)$.We apply an autoregressive distributed lag model (ARDL)' advanced by Pesaran et al., (2001) to equation 3.2 to obtain the long-run effects based on the environmental Kuznets' Curve (EKC) procedure. In doing this, the ARDL bound testing cointegration approach is applied to check for long-run cointegration amongst the variables. The dynamic short-run effects were estimated through a restricted error correction model, derived from a flexible ARDL model is expressed as follows:

$$\Delta \text{lnEFP}_t = \alpha_0 + \sum_{k=1}^{n1} \omega_k \Delta \text{lnEFP}_{t-k} + \sum_{k=0}^{n2} \eta_k \Delta \text{lnGDP}_{t-k} + \sum_{k=0}^{n3} \xi_k \Delta \text{lnGDP}^2{}_{t-k} +$$

$$\sum_{k=0}^{n4} \ell_k \Delta \text{lnEU}_{t-k} + \sum_{k=0}^{n5} \partial_k \Delta \text{lnGLO}_{t-k} + \sum_{k=0}^{n6} \vartheta_k \Delta RQ_{t-k} \; \theta ECT_{t-1} + \varepsilon_t \quad (3.3)$$

Where Δ is the difference' operator, generically defined by $\Delta y_t = y_t - y_{t-1}$ while ECT_{t-1} is first lagof the error correction term is derived from the residual of the long-run effects in equation 3.2.The long-run coefficients are normalized as follows:

$\theta_i = \beta_i / (1 - \sum_{j=1}^{q} \omega_k)$, where $i = 1,2,3,4,5$, and error correction term (ECT) is obtained as:

$$ECT_{t-1} = \theta_1 \ln\text{EFP}_{t-1} + \theta_2 \ln\text{GDP}_{t-1} + \theta_3 \ln\text{GDP}^2{}_{t-1} + \theta_4 \ln\text{EU}_{t-1} + \theta_5 \ln\text{GLO}_{t-1} + \theta_6 RQ_{t-1}.$$

The ECM captures the adjustment speed from the short-run disequilibrium path toward the long-run equilibrium. Unlike existing cointegrating models, the ARDL bounds testing approach has the underlying advantage of suitability regardless of whether the variables are mutually integrated 1(0), or integrated of I(1). The model is flexible and usable regardless of small or how large the study period is. More of the ARDL model's advantage is that it estimates both long-run and short-run effects simultaneously.

3.3.2 Causality Analysis

To test the causal relations amongst the variables, we applied the vector error correction model (VECM) Granger causality approach, which is capable of investigating causal relationships between variables in the long- and short-run. However, this test is appropriate if proof of cointegration between the variables is available. Long-run causality is obtained from the VECM model via a lag period of the long-run residual. If the coefficient of this model is significant, it denotes that there are long-term relations amongst the variables. On other hand, if f-statistic of the first differenced lagged' independent variable is significant, as a conclusion, we believe there is a short-term causal link amongst the variables.

3.3.3 Data

This research is conducted for South Africa utilizing quarterly data from 1996:Q1 to 2016Q4. The Ecological footprint per capita is the dependent variable, which measures environmental degradation. Independent variables in this study are economic growth and its square term measured by Gross Domestic Product (GDP) per capita (constant 2010-US$), energy use is the primary energy supply calculated by the energy production plus energy imports, minus energy exports, minus international bunkers, then plus or minus stock changes. It is measured in million tonnes and tonnesper 1000 USD. Other independent variables included in the model are globalization measured by the globalization index, which includes political, social, and economic aspects of globalization.

The political aspect of globalization takes about 26% of weight, social globalization carries 38% weight while the economic aspect of globalization takes 36% of weight in the index. The data for the real GDP per capita is collected from the World Development Indicators (WDI)/World Bank Database while energy use is collected from the Organization for Economic Cooperation and Development (OECD) database. The ecological footprint per capita is obtained from the Global Ecological Footprint database. We got data for globalization from KOF Swiss Economic Institute via http://globalization.kof.ethz.ch/. While regulatory quality, measured by −2.5 for weak governance and + 2.5 for strong governance, is obtained from the Worldwide Governance Indicators database.

3.4 Empirical Results

3.4.1 Preliminary Analysis

This section begins with the preliminary analysis of variables. Except for regulatory quality, the variables are used in their natural logarithmic forms. From Figure 3.1, a visual inspection of the series under study shows that they are mostly time trending with the possibility of structural break in the data series. Summary statistics are presented on Table 1; Panel A. Number of observations for each of the series is eighty-four. Positive mean values are observed for all variables expect for energy use. Thus, the standard deviation values range from approximately 0.067388 to 1.911535, indicating that ecological footprint has the lowest level of variation, the squared term of income is the most volatile while energy use has the least variation in terms of the range between the maximum- and minimum- values.

The level of income and its squared term, as well as globalization negatively, are skewed while ecological footprint and regulatory quality are positively skewed. We also observe that the variables all indicate positive kurtosis with evidence that there is no concern about extreme values in the data. However, except for ecological footprint and energy use, we reject the null hypothesis of the normal distribution as shown by the Jarque-Bera statistics.

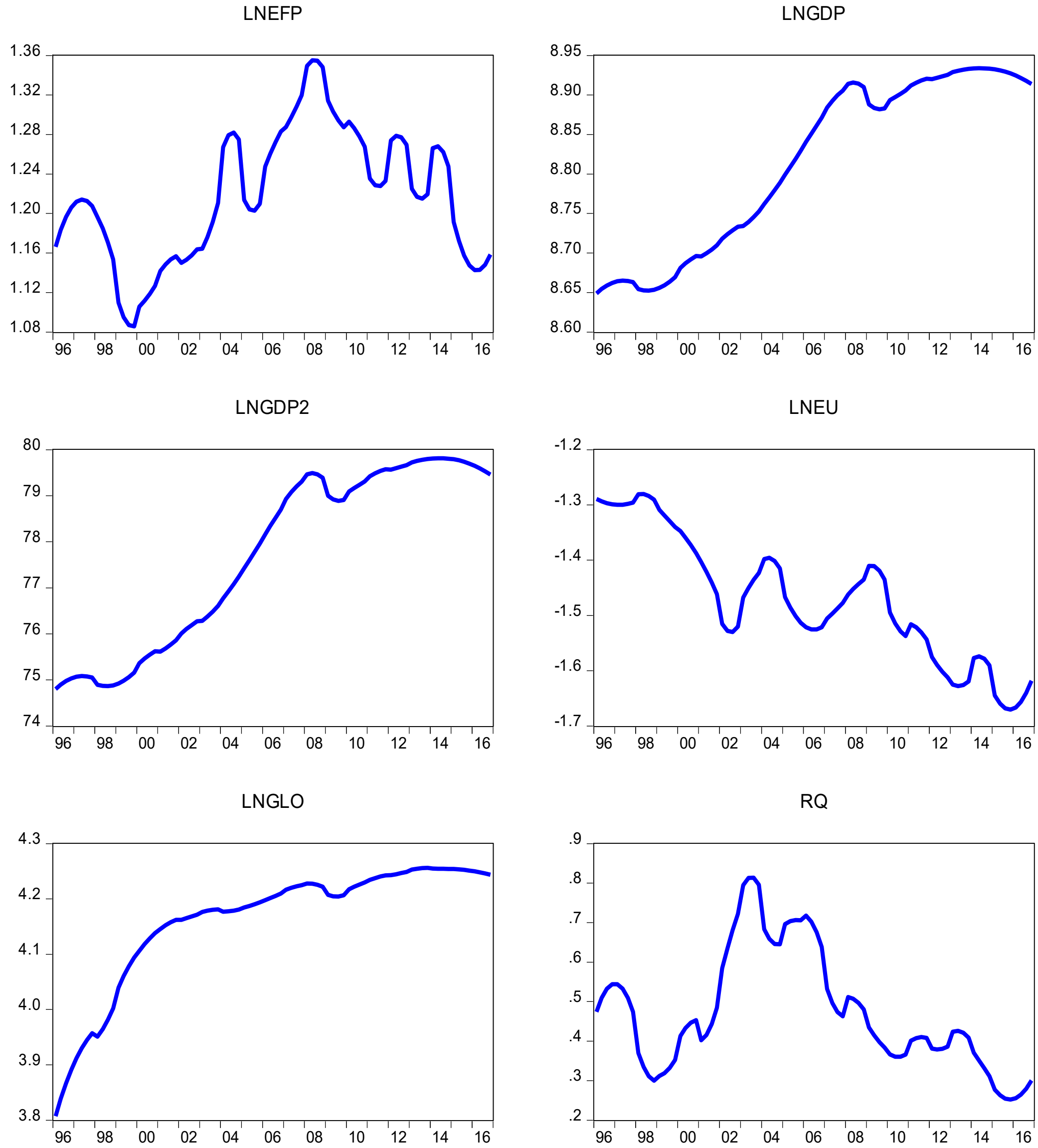


Figure 3.1: Log of EFP, Log of GDP, Log of EU, Log of GLO and RQ

Furthermore, Panel B of Table 3.1 presents the Pairwise Correlations amongst the variables employed. The results show that the correlation coefficients of the series are mostly positive and significant. Particularly, apart from energy use, correlations between ecological footprint and all the variables is positive but statistically insignificant in the case of regulatory quality. The correlation between GDP and it'ssquared with energy use and that of regulatory quality are negative and significant.We also find energy use to be negatively and significantly correlated with globalization while globalization has a negative and insignificant correlation with regulatory quality.

Table 3.1: Panel A's Descriptive Statistics and Panel B's Pairwise Correlations

PANEL A - Descriptive Statistics

Variable	LNEFP	LNGDP	LNGDP2	LNEU	LNGLO	RQ
Mean	1.217396	8.813711	77.69317	-1.471172	4.161638	0.472017
Median	1.213242	8.856209	78.43247	-1.481508	4.202999	0.429599
Maximum	1.355165	8.933867	79.81399	-1.280471	4.256168	0.813614
Minimum	1.085775	8.648795	74.80166	-1.670483	3.807255	0.252167
Std. Dev.	0.067388	0.108647	1.911535	0.114170	0.111392	0.149881
Skewness	0.059771	-0.310610	-0.305017	0.082121	-1.591282	0.646166
Kurtosis	2.182308	1.400493	1.396033	2.020763	4.555952	2.455431
Jarque-Bera	2.390188	10.30518	10.30698	3.450584	43.92396	6.883372
Probability	0.302676	0.005784	0.005779	0.178121	0.000000	0.032011
Sum	102.2612	740.3517	6526.226	-123.5785	349.5776	39.64939
Sum Sq. Dev.	0.376918	0.979748	303.2792	1.081891	1.029871	1.864547
Observations	84	84	84	84	84	84

PANEL B - Pairwise Correlations

Probability	LNEFP	LNGDP	LNGDP2	LNEU	LNGLO	RQ
LNEFP	1.000000					

LNGDP	0.595289	1.000000				
	0.0000	-----				
LNGDP2	0.594617	0.999994	1.000000			
	0.0000	0.0000	-----			
LNEU	-0.181521	-0.842573	-0.842388	1.000000		
	0.0984	0.0000	0.0000	-----		
LNGLO	0.365673	0.840312	0.839210	-0.837171	1.000000	
	0.0006	0.0000	0.0000	0.0000	-----	
RQ	0.150496	-0.269243	-0.271859	0.199307	-0.080689	1.000000
	0.1718	0.0133	0.0124	0.0691	0.4656	

Source: Authors' computation

The empirical investigation of the role of regulatory quality with globalization together with roles of energy expansion and income level on ecological footprint examined by first of all subject the variables for stationarity test through the Lee-Strazicich unit root tests with one structural break. The results as shown in Table 3.2 provide evidence that the variables are not stationary at level. This implies the null hypothesis of stationarity is overwhelmingly rejected for all variables only after the test is conducted with first difference. By this, we conclude that all variables are conveniently integrated of order one I(1).[1]

Table 3.2: Lee-Strazicich Unit Root Test

	L-S Test at Level		**L-S Test at First Difference**	
Variables	**LM Statistic**	**Break-Point**	**LM Statistic**	**Break-Point**
lnEFP	-1.8077 (8)	1999:Q4	-5.0638 (7)***	1999:Q3
lnGDP	-2.6759 (8)	2009:Q2	-3.8268 (0)**	2002:Q1
$lnGDP^2$	-2.6572 (8)	2009:Q2	-3.8299 (0)**	2002:Q4
lnEU	-3.1194 (5)	2002:Q4	-4.8234 (7)***	2008:Q4
lnGLO	-1.9779 (8)	1998:Q4	-3.2092 (8)*	2008:Q4
RQ	-2.2897 (8)	2006:Q4	-5.0478 (0)***	2003:Q2
Critical Values				
1 Percent	-4.084		-4.084	
5 Percent	-3.487		-3.487	
10 Percent	-3.187		-3.187	

Note: Authors' computation. ***, ** and * denote levels of significance at 1 percent,5 percent, and 10 percent respectively.

We tested for cointegration amongst the variables using ARDL Bounds Testing Approach advanced by Pesaran et al. (2001). The results of the cointegration are presented in Table 3.3. According to the results, we find that the null hypothesis of

[1]The results of the unit root tests are supported by the time-plots of the variables presented already in Figure 1.

no co-integration in the presence of structural break could not hold at a 5% level of significance. Therefore, we conclude that there is a common long-run relationship among the variables in the presence of structural breaks.

Table 3.3: Results of Co-integration using ARDL Bounds Testing Approach

Test Statistic	Value	Level of Significance	Lower Bound (0)	Upper Bound (1)
F-statistic	6.7562***	10%	2.26	3.35
K	5	5%	2.62	3.79
		2.5%	2.96	4.18
		1%	3.41	4.68

Notes: *** denotes that the null hypothesis of no co-integration is rejected at 1% level of significance. The critical value is determined where $k = 5$ independent variableswith unrestricted intercept and no trend. The maximum lag order is 3 and the optimal lag order is selected by the Akaike Information Criterion (AIC).

Table 3.4 discloses the short-run effects of the explanatory variables on ecological footprint via findings from conditional error correction regression. According to the results, a percentage increase in GDP would increase ecological footprint by about 18.92 percent while a percentage increase. Energy utilization also has a significant positive relation with the ecological footprint, i.e., if energy consumption rises by one percent, the ecological footprint rises by about 0.47 percent while other factors remain unchanged. Conversely, a percentage increase in globalization would reduce ecological footprint by about 1.042 percent while the coefficient of regulatory quality suggests a negative and statistically insignificant effect on ecological footprint.

Table 3.4: Long- and Short Run Coefficients

Variable	Coefficient	t-Statistic	Prob.
C	90.773***	6.6311	0.0000
D(LNEFP(-1))	0.4463***	4.7254	0.0000

D(LNEFP(-2))	0.3255***	3.0814	0.0031
D(LNGDP)	18.917***	5.9448	0.0000
D(LNGDP(-1))	0.9188	1.4158	0.1621
D(LNGDP(-2))	0.6697	1.3999	0.1668
D(LNEU)	0.4721***	4.9589	0.0000
D(LNEU(-1))	-0.3138**	-2.6720	0.0097
D(LNEU(-2))	-0.2566**	-2.2682	0.0270
D(LNGLO)	-1.0424***	-4.5682	0.0000
D(RQ)	-0.0329	-0.7440	0.4599
D1998Q4	0.0036	0.2883	0.7742
D1999Q4	-0.0120	-0.9615	0.3402
D2002Q4	0.0115	0.9293	0.3565
D2006Q4	-0.0006	-0.0473	0.9624
D2009Q2	-0.0003	-0.0155	0.9877
ECT(-1)	-0.4088***	-6.6312	0.0000
Long-Run Coefficients			
LNGDP	50.956*	1.8870	0.0641
LNGDP2	-2.9538*	-1.9267	0.0588
LNEU	0.6992***	8.0564	0.0000
LNGLO	-0.0699	-0.5378	0.5928
RQ	-0.2336***	-3.8261	0.0003
Residual Diagnostics		**Statistic**	***p*-value**
ARCH Test for Heteroscedasticity [1]		0.2827	0.5964
Breusch-Godfrey Serial LM Test [1]		1.2483	0.2685
Ramsey RESET Test [1]		0.4994	0.6194
Jarque-Bera Normality Test		18.060	0.0000
CUSUM		Stable	
CUSUM SQ.		Stable	

Note: ***and ** denote significance at 1%, 5%, and 10% significance level, respectively. The maximumlag order selected is 3 based on Akaike Information Criterion [AIC].

In the long term, we find that a rise in GDP by one percent increases ecological footprint by about 50.956 percent while an increase in the squared term of GDP by 1percent delink ecological footprint by about 2.953 percent. This confirms the validity of EKC hypothesis for South Africa. Moreover, the coefficient of regulatory quality is not only significant but negatively related to ecological footprint. A unit change in regulatory quality would lead to 0.234 decline in environmental degradation through its effect on ecological quality. Furthermore, a percentage rise in globalization decreases ecological footprint by 0.0699 percent while a percentage rise in energy utilization increases ecological footprint by 0.699 percent. Additionally, we capture break points identified through L-S unit root test into our estimation to determine whether the breaks are statistically significant or not. Results as shown in Table 3.4, shows that the break years are all not statistically significant.

Following these estimations, the diagnostics tests of Jarque Bera normality test, Ramsey RESET test, Breusch Godfrey Langrage multiplier test, and the ARCH test for conditional heteroscedasticity are performed. All results show that there is a normal distribution of the error terms, no serial correlation and heteroscedasticity. There also is evidence that the functional form of the model is well specified. Finally, Figure 3.2, which reveals the cumulative sum (CUSUM) and cumulative sum of squares (CUSUMsq) depicts that the model parameters are stable.

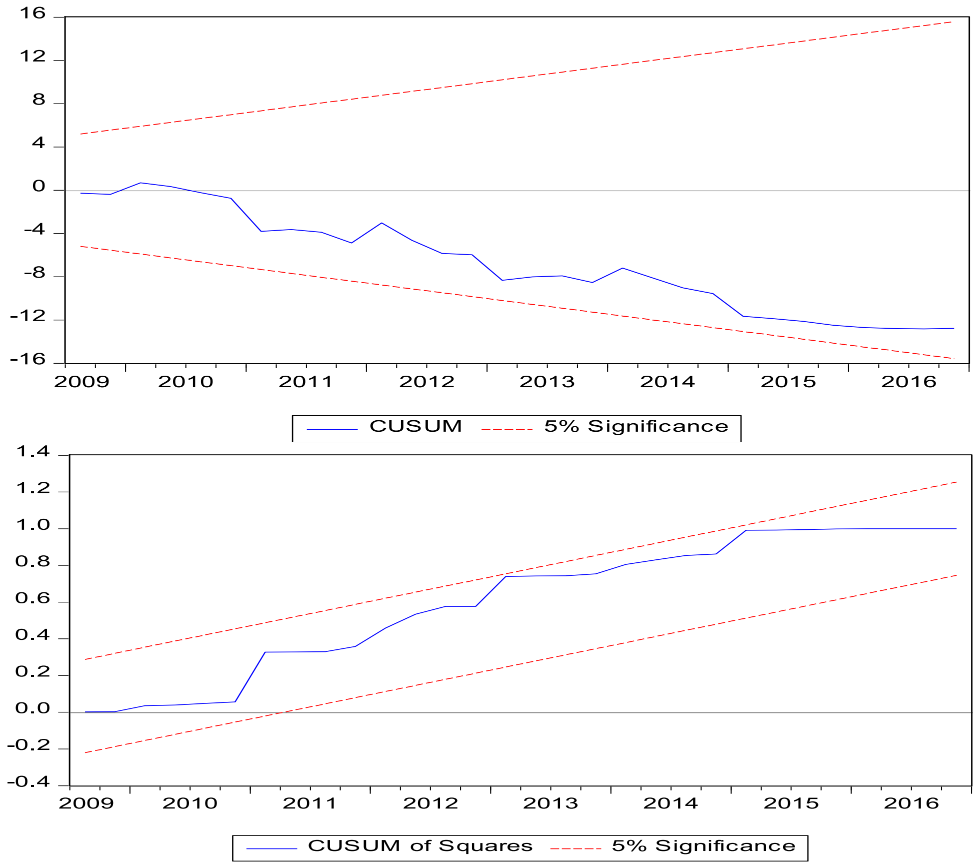
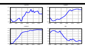


Figure 3.2: CUSUM Test and CUSUM of Squares Test

Causality test results given in Table 3.5 indicate a long-run causal effect running from economic expansion, energy use, globalization with regulatory quality to ecological footprint. In other words, the past values of economic expansion, energy utilization, and globalization with regulatory quality can predict the level of ecological footprint in the long-run for South Africa. The findings concur with Shahbaz et al. (2017b); Rafindadi and Usman 2019; Usman et al. (2020d); Ike et al. (2020b) Gungor et al. (2020). In short-run, a causal relationship runs from ecological footprint to regulatory quality, GDP to regulatory quality, and globalization to energy use. Evidence of unidirectional causality running from energy use to regulatory quality and energy use to ecological footprint was also found. The finding that globalization causes energy use is agreed with Rafindadiand Usman (2019), and Usman et al. (2020a).

Table 3.5: Result of Causality Test

	Short-Run Causal Relationship						**Long-Run**
Dep. Variable	lnEF	lnGDP	$\ln GDP^2$		lnGLO	*RQ*	ECM_{t-1}
lnEF	—	3.5138 (0.3190)	3.4492 (0.3274)	10.428 (0.0153)	4.3184 (0.2291)	2.7175 (0.4373)	-0.5629^{***} [-5.086]
lnGDP	0.1324 (0.9877)	—	2.4453 (0.4853)	0.4941 (0.9202)	0.6234 (0.8911)	2.9638 (0.3972)	—
$\ln GDP^2$	0.1331 (0.9876)	2.4531 (0.4838)	—	0.4944 (0.9201)	0.6290 (0.8898)	2.9681 (0.3966)	—
lnEU	0.0300 (0.9986)	1.6411 (0.6501)	1.6735 (0.6428)	—	0.0064 (0.9999)	2.2815 (0.5161)	—
lnGLO	0.3287 (0.9546)	0.2716 (0.9653)	0.2781 (0.9641)	0.2134 (0.9754)	—	1.2678 (0.7368)	—
RQ	10.575 (0.0143)	8.3872 (0.0387)	8.2509 (0.0411)	6.7958 (0.0787)	1.4176 (0.7014)	—	—

Notes: ***and** denote rejection of the null hypothesis at 1% and 5% significant levels. p-values are presented in parenthesis ( ) and t-Statistic values are denoted by [ ]. The maximum lag order selected is 3 based on Akaike Information Criterion [AIC].

3.4.2 Discussion of Findings

From the results presented in this study, it is depicted that a rise in an economic expansion is attributed to a rise in ecological footprint while a squared term of economic growth delinks ecological footprint. In other words, at the lower levels of income captured by real GDP, it has a positive relationship with ecological footprint and by implication environmental degradation, but at high levels of income represented by real GDP squared, an increase in income reduces environmental degradation. The implication of this result for South Africa and other developing countries is that at the first stage of development, a country is bound to experience environmental degradation in their quest for development but as their income level increases, they will overcome the challenge of environmental degradation. Therefore, our finding confirms the EKC hypothesis for South Africa, which corresponds with the earlier pioneering work of Grossman and Krueger (1991). It also validates Rafindadi& Usman (2019) who discovered EKC in South Africa and Ike et al. (2020b) who also find EKC hypotheses for a group of 15 oil-producing nations.

Furthermore, energy utilization has significant positive relations with the ecological footprint, which by implication causes environmental degradation in both the short- and long runs. This finding is an indication of the massive use of "unclean" energy such as energy sourced from fossil fuels in South Africa. This confirms the major findings of Dogan and Turkekul (2016) onthepositive effects of energy consumption on CO2 emission in the US. Our findings also agree with Mesagan et al. (2018); Rafindadi and Usman (2020) and Katircioglu and Katircioglu (2018) who find energy consumption to be associated with environmental deterioration in Nigeria, Turkey, and Brazil.

The negative effect of globalization on the ecological footprint in both the long- and short-run implies that embracing globalization is beneficial to South African environmental improvement. Therefore, as income level increases, globalization would serve as one of the tools, which South African may use to overcome the challenge of environmental degradation caused by economic growth activities. This result is empirically proven to be different from the situation in India documented by Shahbaz et al., (2015) that globalization has a positive correlation with environmental pollution. However, our finding agrees with the results of Rafindadi and Usman (2019) in South Africa, Shahbaz et al. (2017) in China, and Saint et al. (2019) in Italy.

Finding on regulatory quality in South Africa suggests that regulatory quality effect on ecological footprint is negative both for the long-run and short-run. The effect of the short-run is quite weak. This means regulatory quality is not strong enough statistically to diminish environmental degradation in the near term. Otherwise put, the impact of regulatory quality in environmental degradation is significant only in the long-run. This outcome is contrary to Adedoyin et al. (2020) that discovered regulatory quality does not reduce CO_2 emissions in BRICS countries, including South Africa, but similar to Samimi et al. (2012) who confirm that environmental improvement could be traceable to effective regulatory quality. The negative but insignificant effect of regulatory quality observed in the short term and some significance of the regulatory quality in the long term, indicate that if the regulatory quality is intensified, there is the possibility to curb the environmental challenges in South Africa.

3.5 Conclusion and Policy Implications

The huge benefits of globalization also come with its attendant side effects; one of which is indiscriminate energy use, which has been confirmed to be unfriendly to the environment. Effective regulation is one of how society strives to overcome this challenge. This paper perhaps tested the role of globalization and regulatory quality in the classical EKC model, which incorporates energy consumption for South Africa. Our study sample covers 1996:Q1 to 2016:Q4 and the ARDL approach is used in achieving this objective by capturing the effects of structural breaks.

We find that EKC is valid for South Africa and that environmental degradation is highly induced by energy consumption. More importantly, we find that environmental degradation will reduce with increased globalization and regulatory quality. This suggests therefore that globalization and regulatory quality are beneficial to South Africa in this context. Based on these findings, we therefore, recommend the energy and environmental policy makers to strengthen regulatory institutions and regulatory laws towards achieving environmental improvement in South Africa. This can be done by restructuring political and economic institutions by redefining the existing laws, establishing new laws of energy and environment as well as inculcating value reorientations among government agents and the citizens. Also, as the need to develop South Africa continues, the decision-makers in government need to expand energy sources to minimize heavy reliance on coal consumption.

In this case, to enhance the use of greener energy sources including wind, solar, biomass, nuclear power, and hydroelectric power, the government should take proactive efforts so as to maintain South Africa's EKC in a steady state. Furthermore, increasing the pace of globalization could combat the environmental effect of economic growth through the technological advancements and technical know-how associated with the trend of globalization. Therefore, to optimally gain from globalization, we suggest the need to strengthen carbon tax, increase the supervision of energy-intensive activities, and ensure stringent compliance with carbon emissions laws to prevent the adverse impact of globalization on the environment through the projected rapid increases in energy consumption. Finally, effort should be made by the policy makers to adopt laws that promote the efficient use of energy in South Africa.

Chapter 4

ARE IMPACTS OF RENEWABLE ENERGY, GLOBALIZATION AND ECONOMIC GROWTH ON ENVIRONMENTAL SUSTAINABILITY ASYMMETRIC IN SOUTH AFRICA? A RECONSIDERATION USING NONLINEAR-ARDL APPROACH

4.1 Introduction

Over the years, the factors determining environmental sustainability have been well established. The importance of variables such as renewable energy, globalization, and economic growth as tools to sustain environmental quality become clearer in recent times (see Shahbaz et al. 2017a&b; 2018; Rafindadi& Usman 2019; 2021; Iorember et al. 2021; Usman et al. 2020a; 2020b; Musa et al. 2021). Given an increase in empirical studies, it is realized that a large number of scholars believe that the impact of economic variables such as renewable energy consumption, globalization, and economic growth on environmental sustainability is complicated. Most studies believe that the relationship between economic growth and environmental degradation, for example, is essentially symmetric. In other words, a change in economic growth has the same effect – whether positive or negative on environmental degradation. However, recent studies have cast doubts on the reliability of this assumption, claiming that the relationships among economic variables are possibly marked by asymmetries or non-linearity (See Usman & Elsalih, 2018; Usman 2020; Balcilar et al. 2021a&b; Balcilar& Usman, 2021).

The pursuit of economic growth in South Africa has resulted in largely embracing globalization policy to boost trade and inflows of foreign investments (See Rafindadi& Usman 2019). With the inclusion of South Africa in the emerging economic bloc alongside Brazil, Russia, India, and China, the pace of globalization and liberalization of trade policies become deeper, and this ultimately stimulates economic growth. Specifically, the average growth rate in South Africa rose to 4.3% between 1996 and 1997 while the nominal GDP for 2011 was estimated to be 400 billion USD. However, following the consequences of the COVID-19 pandemic, the GDP growth became negative (i.e. -1.8%) in the 3rd quarter of 2021. This was short-lived, and by the last quarter of the same year, the country recorded 1.4% GDP growth and 1.9% in the first quarter of 2022. Furthermore, South Africa is ranked 14th largest emitter of GHG and 7th top emitter of fossil fuel carbon dioxide in the world. The country emitted 42% of the continental GHG as of 2008 (see IEA, 2014). As reported recently by Andrew and Peters, (2021), the annual share of global CO_2 emission in South Africa dropped to 1.30% in 2020.

While South Africa is richly endowed with clean energy resources that can be replaced with fossil fuels, most of these have remained largely untapped. To reduce the level of emissions in South Africa, it is clear that the country needs to accelerate the pace of energy transition toward renewables (See Usman et al. 2020b). In 2003, a white paper on renewable energy in South Africa came into existence. The aim is to ensure equitable levels of investments of national resources in clean energy technologies which include biomass, solar, hydro, wind, etc. This actually laid the foundation for the promotion of clean energy technologies and created a climate for investing in the renewable energy sector in South Africa. Consequently, in May 2011, the Integrated Resource Plan (IRP) was promulgated, which ambitiously targets 17800 MW of renewable energy by 2030, while almost 5000 MW was planned to be achieved by 2019. In implementing the IRP 2019 through the Electricity Regulations Act No. 4 of 2006, it was discovered that in 2017, about 6422 MW of electricity had been procured from 112 Renewable Energy Independent Power Producers bidding windows, which are purely competitive. 3162 MW of electricity generation capacity of 6422 came from 57 IPP projects, which have been connected to the national electricity grid as of June 2017 (see MRE, 2021).

Furthermore, several energy policies and bid windows have been implemented to reduce the level of emissions and promote the procurement of renewable energy resources. These include the 2003 implementation strategy for the control of exhaust emissions from road-going vehicles in South Africa, climate change response strategies of 2004 and 2005, cleaner energy production strategies of 2005; energy efficiency strategy of 2005 to name but a few.

Theoretically, economic growth causes environmental degradation. This is because as economic activity increases in a way to raise the standard of living of the people, unclean energy utilization is required, which of course increases the level of carbon dioxide concentration in the atmosphere. This argument is a subject matter in the environmental Kuznets curve literature (See Katircioglu&Katircioglu 2018, Usman et al., 2019; Gungor et al. 2020; 2021; Usman et al. 2020b; Ike et al. 2020a,b&c; Agbede et al. 2021). Furthermore, on the one hand, it has been established in the literature that globalization may have the potential to improve environmental quality through diminishing natural resources, decreasing deforestation, lowering energy prices, and trading technical knowledge to spur the growth process (Shahbaz et al. 2018; Rafindadi& Usman 2021). Also, Gozgor et al. (2020), in their view, show that the upper level of economic globalization could encourage renewable energy. Globalization, on the other hand, can promote economic activity and thus increase energy consumption and environmental degradation if other parameters remain constant (Cole 2006; Usman et al. 2020b).

Another variable that has been emphasized in recent times as one of the major determinants of environmental sustainability is the consumption of renewable energy. The policy to transit from fossil oil consumption to clean and alternative energy systems has been documented as an appropriate measure to reduce the level of greenhouse gas emissions. This is because renewable energy has little or no environmental degradation effect as demonstrated by Alola et al. (2021), Usman et al. (2022); Ike et al. (2020a). That is why many countries across the world have adopted renewable energy consumption as a strategy to mitigate environmental degradation.

With the high level of emission of greenhouse gases, such as CO2 from the use of fossil fuels, particularly coal and petroleum products in South Africa, it is important to properly understand the factors accounting for environmental degradation in this country. To this extent, our paper contributes to the literature by revisiting the effects of economic growth, globalization, and renewable energy consumption on a sustainable environment in South Africa. The nonlinear model through the nonlinear autoregressive distributed lag model (NARDL) developed by Shin et al. (2014) is applied to examine how shocks to economic growth, renewable energy, and globalization change the behaviours of CO_2 emissions in South Africa. By this, we relax the assumption of symmetric and linearity which tends to render the previous studies based on a linear model unreliable for a policy decision. This is because if the existing relationship is asymmetric or nonlinear, such a result would be spurious and erroneous.

Therefore, the remainder of this paper is organized thus: Section 4.2 provides details of literature reviewed. Section 4.3 is for methodology of the study. The empirical results and discussion were presented in Section 4.4 while Section 4.5 concludes the paper with policy recommendations.

4.2 Literature Review

The literature on the impact of economic growth, renewable energy consumption, and globalization is mostly found in the case of linearity which holds that environmental degradation responds linearly to a change in variables such as economic growth, renewable energy, and globalization. In this section, we split the review into three sub-sections:

4.2.1 Economic Growth and Environmental Degradation

There is voluminous literature on the relationship between economic growth and environmental degradation. Most of these studies are conducted within the framework of the EKC. For example, Ozatac et al. (2017) tested whether the EKC hypothesis is valid for Turkey. The results revealed that an increase in economic growth promotes environmental degradation with evidence of a turning point estimated to be 16,648 US dollars in the long run. Katircioglu and Katircioglu (2018) examined the role of economic growth in the CO_2 emissions of Turkey. Their results documented a U-shaped association between economic growth and CO_2 emission.

This suggests that an increase in economic growth reduces environmental degradation over the studied period. Inglesi-Lotz and Bohlmann (2014) test the EKC hypothesis in South Africa using the ARDL method. They find no evidence in support of the hypothesis, suggesting that the economy is at the early stage of transition. Usman et al. (2019) tested for the EKC in India by incorporating the effects of energy consumption and a democratic regime. The results found that the EKC in India is characterized by an inverted U-shape, and this is fuelled by the increase in energy consumption. Furthermore, a paper by Shahbaz et al. (2017c), revealed that a positive shock to economic growth exerts upward pressure on environmental degradation while a negative shock to economic growth dampens environmental degradation.

Similarly, Shahbaz et al. (2018) captured the nonlinearity of the effect of economic growth in BRICS countries. The results found that a positive shock to the measure of economic growth (i.e. GDP per capita) increases environmental hazards more strongly than the way in which a negative shock of economic growth decreases the level of environmental hazards. In a recent paper, Ali et al. (2020) based on the EKC procedure, reveal that economic growth has a positive effect on CO_2 emissions in Nigeria and this relationship is characterized by nonlinear. Moreover, Akadiri and Adebayo (2021) find evidence supporting the asymmetric effect of economic growth with respect to environmental degradation in India.

4.2.2 Globalization and Environmental Degradation

In recent times, many studies have examined the effect of globalization on environmental degradation (See Ahmed et al. 2016; Shahbaz, et al. 2017a; 2018, Rafindadi& Usman 2019; 2021). The results from the existing literature seem to be mixed. Some studies concluded that globalization increases CO_2 emissions through trade and economic growth, while some studies documented that globalization is an instrument to reduce CO_2 emissions. For example, Ahmed et al. (2016) found that a rise in the pace of globalization increases the demand for energy and consequently increases CO_2 emissions. Shahbaz et al. (2017a) found on the basis of the ARDL model that globalization in China has the capacity to reduce the level of CO_2 emissions. Shahbaz et al. (2018) argue that the effect of globalization on the environment is dependent on whether its net effect is positive or negative. Furthermore, Rafindadi and Usman (2019) and Rafindadi and Usman (2021) discovered that an increase in the pace of globalization is a tool to dampen CO_2 emissions in South Africa. On the basis of linearity, Shahbaz et al. (2018) found that whenever there is the occurrence of a positive change in the global, energy consumption would be triggered to rise which increases CO_2 emissions. On the other hand, a negative shock in globalization reduces energy consumption (i.e. decrease in CO_2 emissions).

Furthermore, using the financial aspect of globalization, Ulucak et al. (2020) test for EKC in emerging countries by measuring environmental degradation based on the ecological footprint. The results show no evidence of the EKC hypothesis. However, financial globalization improves the quality of the environment while urbanization reduces environmental quality. Chen et al. (2019) using a panel of 16 CEE countries indicate that globalization enhances environmental quality due to the technological transfer accompanied by all aspects of economic globalization. Sharif et al. (2020) use a novel quantile ARDL to revisit the impact of tourism and globalization on the environment in China. The results perhaps show that globalization condenses the externalities of the environment emanating from the accumulation of carbon dioxide. Examining the role of energy consumption, globalization, and economic activity on

CO_2 emission in BRICS, Rahman et al. (2021) show from the two main estimators – FMOLS and DOLS that in the long run, energy consumption from the primary source stimulates environmental degradation while globalization dampens environmental degradation measured by the level of CO_2 emissions.

4.2.3 Renewable Energy Consumption and Environmental Degradation

Renewable energy is one of the variables that has been unanimously admitted in the literature to mitigate the effect of environmental pollution (see Apergis et al. 2010; Silva et al. 2012; Shafiei& Salim, 2014; Dogan & Ozturk, 2017; Alola et al. 2019; Paramati et al. 2021; Iorember et al. 2020, Usman et al. 2022). Silva et al. (2012) found that a portion of electricity consumption generated from clean energy dampens the level of CO2 emissions in Denmark, Portugal, and Spain; although, in the US, such effect is insignificant. Dogan and Seker (2016) examined the relationship between renewable energy consumption and environmental quality using a panel of European countries. The results admitted that renewable energy consumption exerts a negative effect on environmental degradation. Conversely, the findings documented by Ben Jebli et al. (2015) show clearly that in Sub-Saharan Africa, the effect of renewable energy in reducing environmental degradation is not visible statistically. Furthermore, Paramati et al. (2021) examined the long-run effect of renewable energy and R&D investment on environmental quality in 25 EU member countries. The results suggest renewable energy consumption reduces environmental degradation over the period of the study. In a recent paper by Usman et al. (2022), which applied the GMM estimation of a PVAR revealed that renewable energy and financial development stimulate environmental quality in the EU-28 countries. Iorember et al. (2022) using the PMG/ARDL find renewable energy consumption as a means to stimulate environmental quality in Africa's OPEC nations. Moreover, Ehigiamusoe et al. (2022) applied a battery of techniques to examine how renewable energy and income level interaction affect the level of environmental degradation in low-income countries. The results show that renewable energy reduces emissions but when it interacts with income, its effect becomes positive.

Given the empirical studies reviewed, it is clear that a lot of papers relied on the assumption of linearity without giving a consideration to a situation where the relationship between the variables is nonlinear or asymmetric. In such a situation, the linear models used by the previous studies may not produce sound and valid outcomes for policy analysis. Therefore, in this study, we check for the presence of asymmetries, and hence apply a nonlinear model via the nonlinear autoregressive distributed lag (NARDL) in order to capture the effect of asymmetries in the relationship between economic growth, renewable energy consumption, globalization, and environmental degradation in South Africa.

4.3 Data and Empirical Model

4.3.1 Sources of Data

Based on data availability, the study uses South African variables such as renewable energy consumption, economic growth, globalization, and CO_2 emissions from 1990 to 2018. The variables' codes, measurement/description, and their sources are summarized in Table 1 below.

Table 4.1: Variable, Measurement and Source

Variable & Code	**Measurement**	**Source**
Carbon Dioxide Emissions (CO_2)	CO_2 Emissions Per capita measured in metric tons	World Development Indicators
Renewable Energy	Share of renewable energy in the	World Development

(RE)	total energy use	Indicators
Income per capita	Gross Domestic Production	World Development
(GDP)	(Constant 2015 USD) per capita	Indicators
Globalization (GLO)	Globalization is measured in terms of three indices: economic, social and political globalization. The economic globalization is perhaps weighted by 36%, social globalization 38% and political globalization 26%.	The KOF Swiss Economic Institute via http://globalization.kof.ethz.ch/.

Source: Authors' computation

4.3.2 Nonlinear Autoregressive Distributed Lag (NARDL) Model

The argument of this paper is that most studies in the extant literature examine the long-run effect of various economic variables based on linear settings with a strong and strict assumption of linearity. This makes the outcomes to be unreliable if the variables have a nonlinear long-run relationship (See Shin et al. 2014). To circumvent this empirically-based problem, we depart from a linear rut to a nonlinear rut by employing the nonlinear autoregressive distributed lag (NARDL) model advanced by Shin et al. (2014). The general form of this model is represented as follows:

$$y_t = \alpha^+ x_t^+ + \alpha^- x_t^- + \mu_t \qquad (4.1)$$

Where α^+ and α^- are referred to as the long-run coefficients. The time series variables x_t^+ and x_t^- represent the regressors which are decomposed into their partial sum of the positive and negative shocks defined as $x_t = x_t^+ + x_t^-$. Hence,

$$x_t^+ = \sum_{j=1}^{t} \Delta x_j^+ = \sum_{j=1}^{t} Max(\Delta x_j, 0) \qquad (4.2)$$

$$x_t^- = \sum_{j=1}^{t} \Delta x_j^- = \sum_{j=1}^{t} Min(\Delta x_j, 0) \quad (4.3)$$

From equations (2) and (3), the cumulative partial sums of the positive and negative changes x_t are represented in the framework of the ARDL(*p*, *q*) model advanced by Pesaran et al. (2001) as shown below:

$$y_t = \sum_{j=1}^{p} \varphi_j y_{t-j} + \sum_{j=0}^{q} (\psi_j^+ x_{t=j}^+ + \psi_j^- x_{t=j}^-) + \varepsilon_t \quad (4.4)$$

where variable x_t is $k \times 1$ vector of dependent variables, φ_j denotes the autoregressive parameter, ψ_j^+ and ψ_j^- represent the parameters that are nonlinearly distributed, and ε_t represents the random error term, assumed to be constant in variance with zero mean. The *p* and *q* are the orders of the lags used in the NARDL model estimations. Therefore, equation (4) can be written within the framework of the error correction model with modification so that asymmetries are captured with respect to the direction of the change in x_t a variable:

$$\begin{aligned}\Delta \ln CO_{2t} &= \alpha_0 + \rho_1 \ln CO_{2t-1} + \beta_1^+ \ln GDP_{t-1}^+ + \beta_1^- \ln GDP_{t-1}^- + \beta_2^+ RE_{t-1}^+ + \\ &\beta_2^- RE_{t-1}^- + \beta_3^+ GLO_{t-1}^+ + \beta_3^- GLO_{t-1}^- + \\ &\sum_{j=0}^{p-1} \delta_i \Delta \ln CO_{2t-j} + \sum_{j=0}^{q-1} \omega_1^+ \Delta \ln GDP_{t-j}^+ + \sum_{j=0}^{q-1} \omega_1^- \Delta \ln GDP_{t-j}^- + \sum_{j=0}^{q-1} \omega_2^+ \Delta RE_{t-j}^+ + \\ &\sum_{j=0}^{q-1} \omega_2^- \Delta RE_{t-j}^- + \sum_{j=0}^{q-1} \omega_3^+ \Delta \ln GLO_{t-j}^+ + \sum_{j=0}^{q-1} \omega_3^+ \Delta \ln GLO_{t-j}^- + \mu_t \end{aligned} \quad (4.5)$$

where Δ is the differenceoperator. The long-run effect of CO_2 emissions is obtained from the estimates of β's normalized on ω's. to normalize equation (4.5), it will be more meaningful and convenient only if cointegration is established between the variables. Therefore, in testing for nonlinear cointegration, we follow the recommendation in Shin et al. (2014) where F-test (F_{PSS}) proposed by Pesaran et al. (2001) and the alternative t-test (t_{BDM}) proposed by Banerjee et al. (1998) are applied. The null hypothesis for asymmetric cointegration test is provided as:

$H_0: x_t^+ = x_t^- = 0$. Moreover, the short-term adjustment coefficients of the effects of economic growth, renewable energy consumption and globalization on environmental sustainability are obtained from the second part of the equation (4.5) i.e., $\sum_{j=1}^{q-1} \omega_j^+$ and $\sum_{j=1}^{q-1} \omega_j^-$ for all $j = 0,...,q-1$.

Another important component of nonlinear ARDL modeling technique is the computation of the asymmetric dynamic multipliers effects of a unit change in variables captured in the model. This provides information concerning asymmetric patterns of the relations amongst the dependent variable and explanatory variables. The cumulative dynamic multiplier effects of the positive and negative shocks of economic growth, renewable energy, also globalization on CO_2 emission is captured via the following equation:

$$m_h^+ = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^+} \quad \text{and} \quad m_h^- = \sum_{j=0}^{h} \frac{\partial y_{t+j}}{\partial x_t^-} \quad \text{with } h = 0,1,2,... \tag{4.6}$$

Where when $h \to \infty, m_h^+ \to x_t^+$, and $m_h^- \to x_t^-$, where x_t^+ and x_t^- remained as previously defined i.e. the positive and negative decompositions of the explanatory variables.

Before applying the nonlinear ARDL model, we test for the asymmetric relationship among the variables by performing the long-run and short-run asymmetry tests. This enables us to check whether an asymmetric relationship exists among the variables. To do this, the WALD test with the null hypothesis $\beta_j^+ = \beta_j^-$ for the long run and $\omega_j^+ = \omega_j^-$ the short run.

4.4 Results and Discussion

From the time series plots of the variables presented in Figure 4.1, it is clear that the carbon dioxide emission is more characterized by fluctuations and structural breaks among the variables for this study. This can be attributed to the aggressive policy thrust of the government to reduce the level of carbon dioxide. The level of carbon dioxide was low in the 1990s but started rising between 2000 and 2015, hence South Africa became the largest emitter of CO_2 in Africa. The growth of GDP is falling in the 1990s but started rising in the 2000s until the global financial crisis interrupted in 2007/2018. Similarly, globalization trends upward, suggesting the rising pace of globalization in the country. The level of renewable energy consumption is downward trending particularly from 1999 to 2007 before it becomes relatively stabilized. This reveals South Africa's poor performance in terms of transiting toward a renewable energy pathway.

Table 4.2 presents the descriptive statistics of the variables employed in this study. From the Table, it can be seen that the mean of renewable energy is the highest, followed by the mean of the GDP while the mean of CO_2 emissions is the smallest. In terms of the volatility of the variables, it is found that apart from renewable energy which is highly volatile, the standard deviation of all the remaining variables indicates low volatility. Furthermore, the skewness of the variables shows that, except for renewable energy, which is positively skewed, the remaining variables are negatively skewed with evidence that their values are within the normal range of zero. However, the values of kurtosis are positive and close to the normal range. Consequently, the probability values of the Jarque-Bera statistic indicate that the null hypothesis of the normal distribution cannot be rejected at a 5% level of significance.

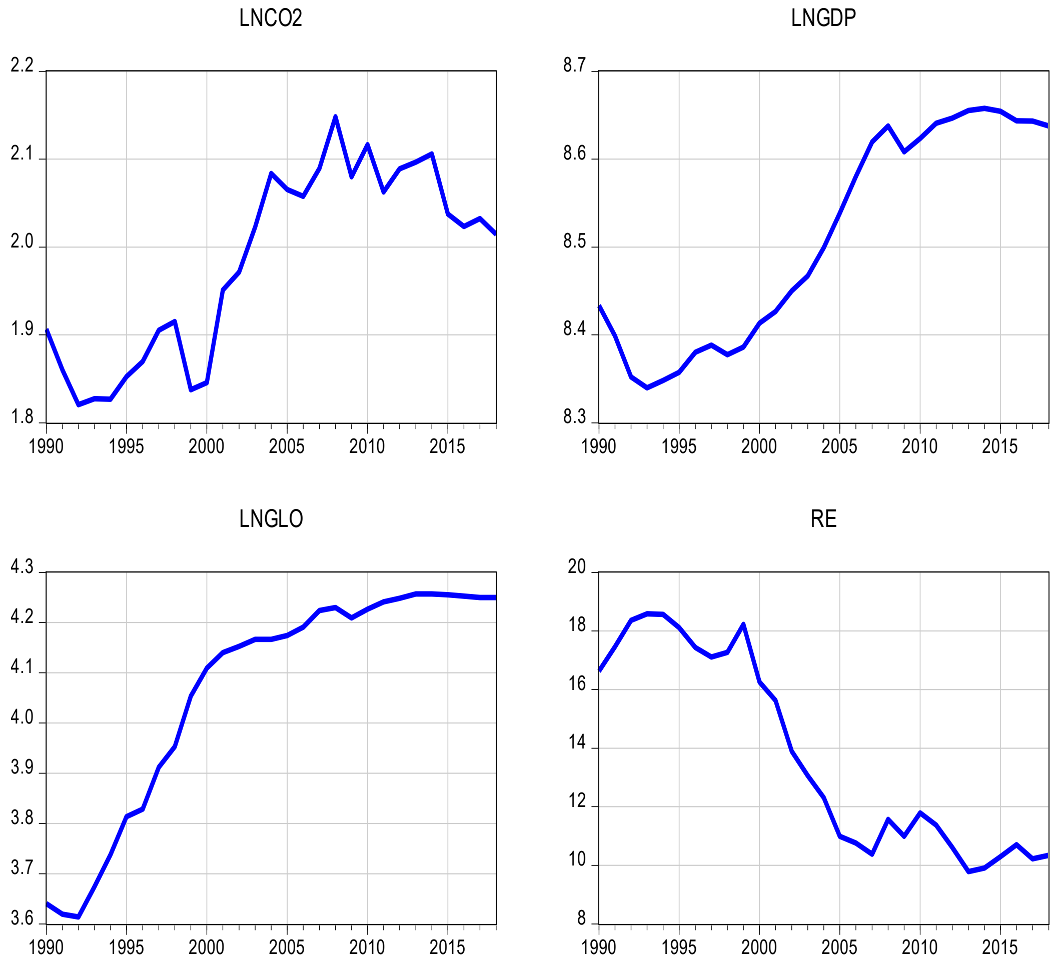


Fig 4.1: Time plots of log of CO2, log of GDP, log of Glo, and RE

Table 4.2: Descriptive statistics

	$LNCO_2$	LNGDP	LNGLO	RE
Mean	1.983242	8.510494	4.063703	13.74512
	2.022624	8.499334	4.166665	12.30710
Maximum	2.148150	8.657735	4.257030	18.58600
Minimum	1.820578	8.339763	3.613617	9.782000
Std. Dev.	0.107092	0.121933	0.226794	3.349450
Skewness	-0.241304	-0.040947	-0.954928	0.274539
Kurtosis	1.548245	1.284849	2.344735	1.340943
Jarque-Bera	2.828110	3.562710	4.926285	3.690199

Probability	0.243155	0.168410	0.085167	0.158010
Sum	57.51403	246.8043	117.8474	398.6085
Sum Sq. Dev.	0.321122	0.416295	1.440199	314.1269
Observations	29	29	29	29

Source: Authors' computation

Table 4.3 presents the results of the BDS linearity test of Brock *et al.* (1987) for nonlinearity. This test focuses on the residuals of the dynamic interactions of the variables. According to the results, the null hypothesis cannot be true at a 1% level of significance. Hence we conclude that applying the symmetric model may provide spurious results. To this extent, nonlinear models are appropriate in determining the dynamic relationship that exists between the variables.

Having established the appropriate models for the relationship between the variables, we step further to determine the stationarity properties of the variables using the standard stationarity test and unit root test with structural breaks.[2] From the results of the Zivot-Andrews unit root test with structural breaks as presented in Table 4.4, it is clear that all the variables are not stationary at their levels. However, after taking their first differences, all the variables become stationary. This means that the variables used in this study follow the I(1) process. Furthermore, we find that the structural break occurs in 2001 for the case of carbon dioxide emissions, 2004 in the case of GDP, 1994 for globalization, and 2002 for renewable energy consumption. The structural break years identified in the results are basically influenced by the macroeconomic policy changes. Particularly, during the period of the study, South

[2] The results of the standard stationarity tests via ADF and PP would be made available upon request from the corresponding author.

Africa has implemented several policies to mitigate the level of carbon dioxide emissions. Some of these policies as shown in Rafindadi and Usman (2019) are the Renewable Energy Policy of 2004; Integrated Clean Household Energy Strategy of 2003, Climate Change Response Strategy of 2004; cleaner energy production strategy of 2005; Implementation Strategy for the Control of Exhaust Emissions from Road-going Vehicles in South Africa introduced in 2003, Energy Efficiency Strategy 2005. All these policies are responsible for the structural breaks identified in the variables' trends.

Furthermore, Table 4.5 shows the results of the nonlinear cointegration between the variables employed. The results provide that the F-statistic is 7.1021 which is far greater than the critical value of 3.99. This rejects the null hypothesis of no cointegration between the variables. The implication of the rejection is that there is clearly an existence of a long-run relationship between the variables.

Table 4.3:BDS Non-Linearity Tests

Variable	BDS Statistic	Standard Error	p-value
$\ln CO_{2t}$	0.1409^{***}	0.00867	0.0000
$\ln GDP_t$	0.1534^{***}	0.00871	0.0000
RE_t	0.1450^{***}	0.00869	0.0000
$\ln GLO_t$	0.2058^{***}	0.01462	0.0000

Notes: Superscript *** shows a significance level at 0.01 with a maximum cor. dimension of 2.

Table 4.4:Zivot-Andrews unit root test with structural breaks

	Z-A test at level	Z-A test at 1st difference

Variables	Statistics	Break date	Statistics	Break date
LnCO2	-6.7376 (1)	2001	$-6.4166\ (2)^{***}$	2001
LnGDP	-3.8455 (1)	2004	$-4.7542\ (1)^{**}$	2009
LnGLO	-2.3139 (1)	1994	$-5.2395\ (2)^{**}$	2001
RE	-4.4732 (1)	2002	$-5.7398\ (4)^{***}$	2002
Critical Values				
1 Percent	-5.34		-5.34	
5 Percent	-4.93		-4.93	
10 Percent	-4.58		-4.58	

Notes: *** and ** denote 1% and 5% significance levels. The lag length is given in thebracket( ).

Table 4.5: Nonlinear Bounds testing cointegration

Model	**Statistic**	**K**
$\ln CO2 = f(\ln GDP, \ln Glo, RE)$	F-Stat: 7.1021^{***}	6
Critical Value Bound Tests	Lower I(0)	Upper I(1)
F-Statistic at 1%	2.88	3.99
F-Statistic at 5%	2.27	3.28
F-Statistic at 10%	1.99	2.94

Notes:*** implies that the null hypothesis of no cointegration is rejected at a 1% level of signific ance and the critical value is determined where $k = 6$ independent variablesunresticted intercept and no trend. The maximum lag order is 2 and the optimal lag order is selected by the Akaike Information Criterion (AIC).

Table 4.6 provides the results of the long-run and short-run coefficients of the function of CO_2 emissions. In the long run, the results provide that a 1% positive shock to economic growth is positively related to a 0.6979% increase in CO_2 emissions while a 1% negative shock to economic growth reduces CO_2 emissions by 5.4099. This implies that a 1% negative shock to economic growth exerts a stronger effect on environmental degradation than the impact a 1% positive change will exert on CO_2 emissions. This finding is therefore contrary to the recent finding discovered by Shahbaz et al. (2018) and Rafindadi and Usman (2021) that the impact of a positive change in economic growth is stronger than when its impact is inverse. The results further discover that the impact of globalization is asymmetric and the negative change to globalization has a stronger impact. Specifically, a 1% positive change in globalization causes CO_2 emissions to gear up by 0.4058% while its negative change of the same percentage exerts a negative pressure of 2.3804% on CO_2 emissions.

This finding is consistent with Shahbaz et al. (2018) who found a different impact of positive and negative change in globalization in BRICS countries concerning energy consumption. Moreover, the results of the impact of renewable energy suggest that renewable energy consumption negatively impacts CO_2 emissions irrespective of the directions of the changes (i.e. positive or negative). A 1% positive change to renewable energy consumption has a 0.0647% effect on CO_2 emissions while its negative change reduces CO_2 emissions by 0.0105%. This result, therefore, suggests that the impact of a positive change in renewable energy consumption has a larger effect on CO_2 emissions than its negative change of the same magnitude. This result is similar to Usman (2022) who found that a positive change in renewable energy is stronger than a positive change of the same size in Nigeria.

For the short-term analysis, the results provide that the previous value of CO_2 emissions reduces environmental degradation in the South African country. The results also find that a 1% positive or negative change in economic growth is said to trigger CO_2 emissions. This result is contrary to Shahbaz et al. (2017c) and

Ranfindadi and Usman (2021) who found that a positive shock to economic growth affects the environment differently from its negative shock. Also, we find that the effect of a 1% positive shock in globalization is positive and insignificant (i.e. 0.3002%) in the short run while the effect of a 1% negative shock in globalization is negative and significant (i.e. -0.5545%). This suggests that the negative effect of globalization is larger on CO_2 emissions in the short run. Furthermore, the effect of both positive and negative shocks on renewable energy consumption is asymmetric. A 1% positive shock to renewable energy significantly reduces CO_2 emissions by 0.0479% while a 1% negative shock to renewable energy reduces CO_2 emissions marginally by 0.0078% but this effect is not significant.

The plausible explanation for this result is that renewables are sourced from clean energy such as solar, hydrogen, wind, geothermal, etc. This kind of energy has no detrimental effects on environmental degradation, and therefore, a fall in its consumption levels may only dampen the magnitude of its impact on CO2 emissions as can be seen in the result presented (i.e. from 0.0479% to 0.0078%). Moreover, the coefficient of a negative shock to renewable energy is not statistically significant. This finding is consistent with Akadiri and Adebayo (2021) that both favorable and unfavorable shocks to renewable energy consumption decrease environmental degradation in India.

Furthermore, we conduct a series of diagnostic tests to determine the fitness and adequacy of the asymmetric ARDL model used. As appeared in Table 6, the first diagnostic test is the Brusch-Godfrey LM test which checks for serial correlation in the model. We find that the null hypothesis of no serial correlation could not be rejected. The test of ARCH for heteroscedasticity and Ramsey RESET confirm that there is no conditional heteroscedasticity in the model and the functional specification is adequate. The normal distribution test of Jarque-Bera indicates that the residuals of the model are normally distributed. Also, to check for the stability of the model, CUSUM and CUSUM of square plots are constructed. The plots as shown in Figure 1, suggest that the model is stable at a 5% significance level.

Table 4.6: Long-run and Short-run Coefficients

Dependent Variable: $\Delta \ln CO_{2t}$			
Variable	**Coefficient**	**Stand. Error**	***p*-value**
$\ln GDP_t^+$	0.6979^{*}	0.3271	0.0510
$\ln GDP_t^-$	-5.4099^{*}	3.0001	0.0929
$\ln GLO_t^+$	0.4058^{**}	0.1491	0.0165
$\ln GLO_t^-$	–2.3804	4.2393	0.5833
$\ln REN_t^+$	-0.0647^{**}	0.0272	0.0319
$\ln REN_t^-$	-0.0105^{***}	0.0021	0.0002
$\Delta \ln CO_{2t-1}$	-0.7399^{***}	0.1419	0.0001
$\Delta \ln GDP_{t-1}^+$	0.5164^{*}	0.2733	0.0796
$\Delta \ln GDP_{t-1}^-$	4.0029^{*}	1.9159	0.0560
$\Delta \ln GLO_{t-1}^+$	0.3002^{**}	0.1013	0.0102
$\Delta \ln GLO_{t-1}^-$	-0.5545^{*}	0.3025	0.0815
ΔRE_{t-1}^+	-0.0479^{**}	0.0208	0.0373
ΔRE_{t-1}^-	–0.0078	0.0089	0.4026
Constant	1.7973^{***}	0.2996	0.0000
Model diagnostics	**Statistic**	***p*-value**	
$\chi^2 - SERIAL$	0.2130	0.6521	
$\chi^2 - ARCH$	0.7215	0.4044	
$\chi^2 - RESET$	0.1241	0.7303	
$\chi^2 - NORMAL$	6.4691	0.0393	

Notes: ***, ** and * denote 1%, 5% and 1% significance levels

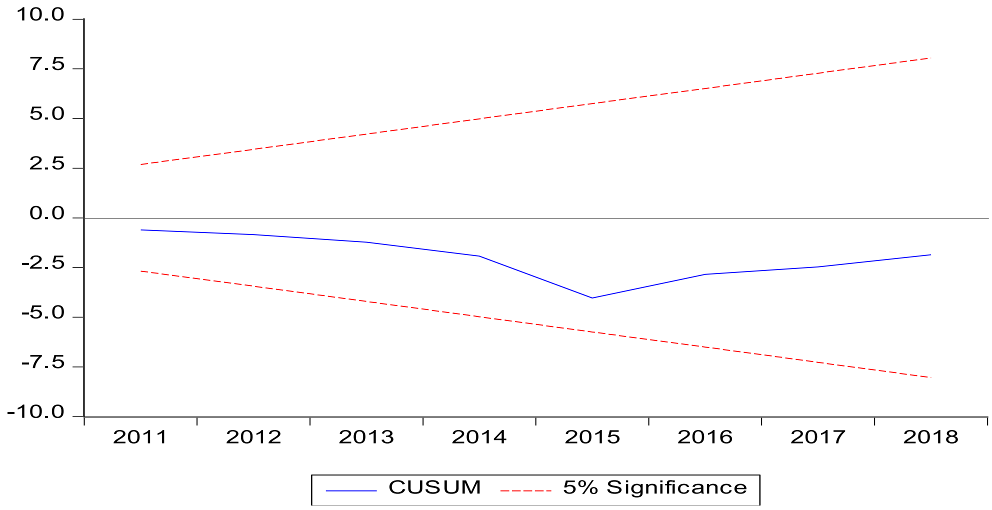


Fig. 4.2: Plot of CUSUM at 5% level of significance

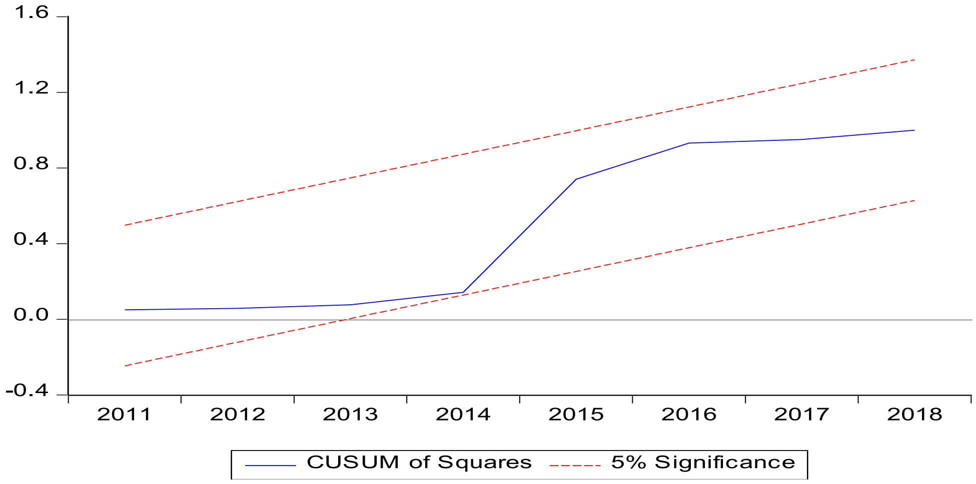


Fig. 4.3: Plot of CUSUM Squares at a 5% level of significance

Dynamic Multiple Adjustments Analysis

Figures 4.4 – 4.6 analyze the dynamic multiplier effect of economic growth, globalization, and renewable energy on a 1% variation in CO_2 emissions. The thick black line denotes the multiplier effects of a positive shock in explanatory variables to a unitary variation in CO_2 emissions. The dotted black line is the multiplier effect of a negative shock in the explanatory variable to a unitary variation in CO_2emissions. The dotted red line is the confidence interval of 95% upon which the significant levels are determined while the horizons are 15. From Fig. 4.4, it is clear that the effect of a positive shock is less than the effect of a negative shock of economic growth, hence the overall multiplier effect is negative with evidence of asymmetry which is statistically significant only up to the 2nd horizon. Also, the effects of both the positive and negative shocks to globalization exert positively and significantly on CO2 emissions. However, the effect of a negative shock to globalization is stronger, making the overall multiplier effect of globalization positive; although there is evidence of an insignificant asymmetry. For renewable energy, we find that the multiplier effect of a positive shock is negative and significant while the multiplier effect of a negative shock is positive and insignificant. So, the overall multiplier effect is negative with evidence that the asymmetry is statistically significant.

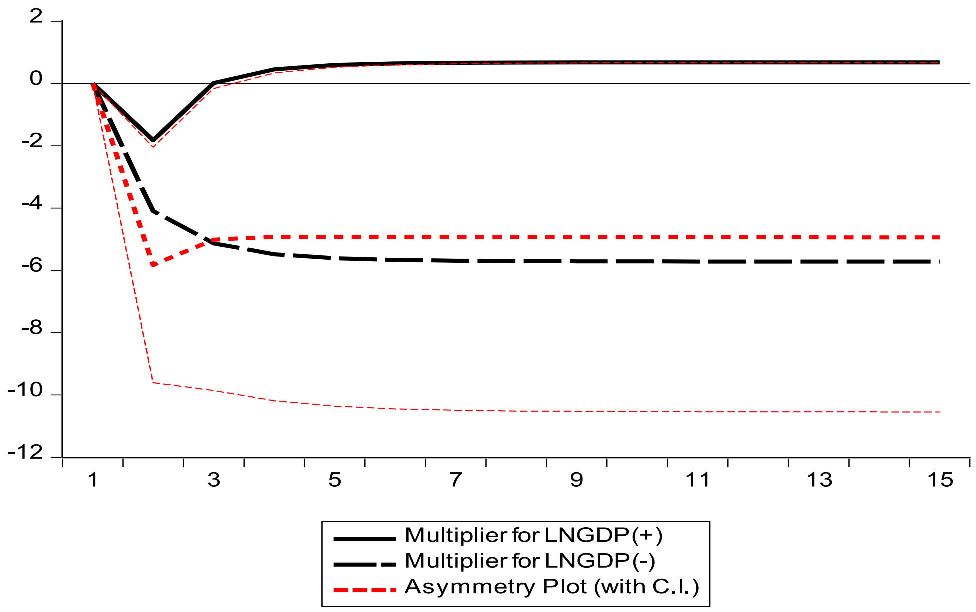


Figure 4.4: Dynamic multiple adjustments of economic growth

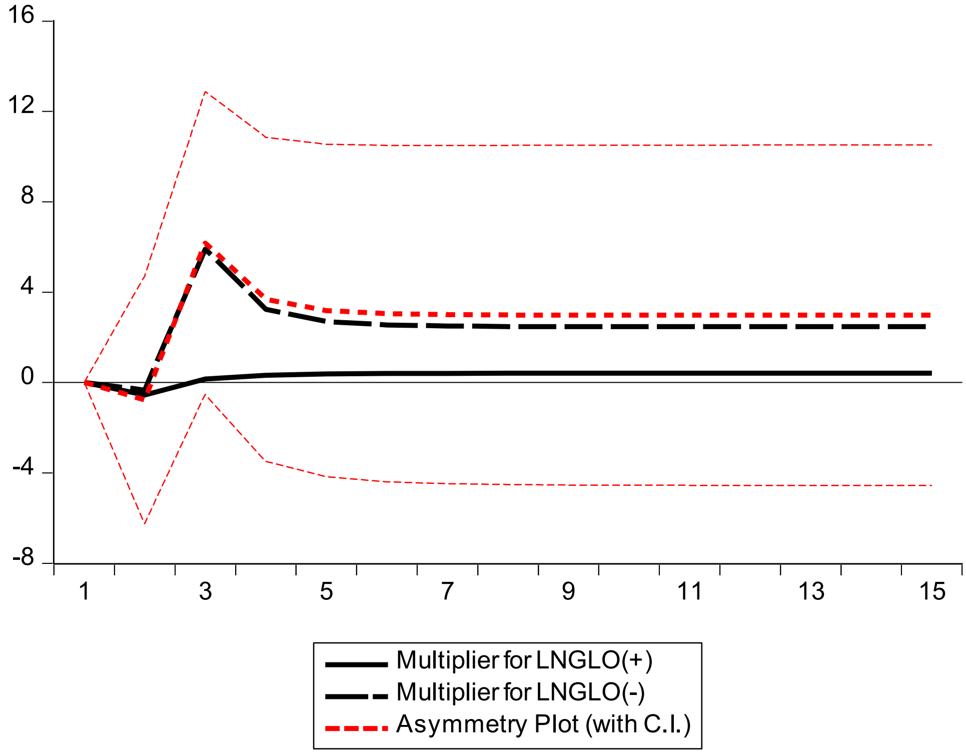


Figure 4.5: Dynamic multiple adjustments of Globalization

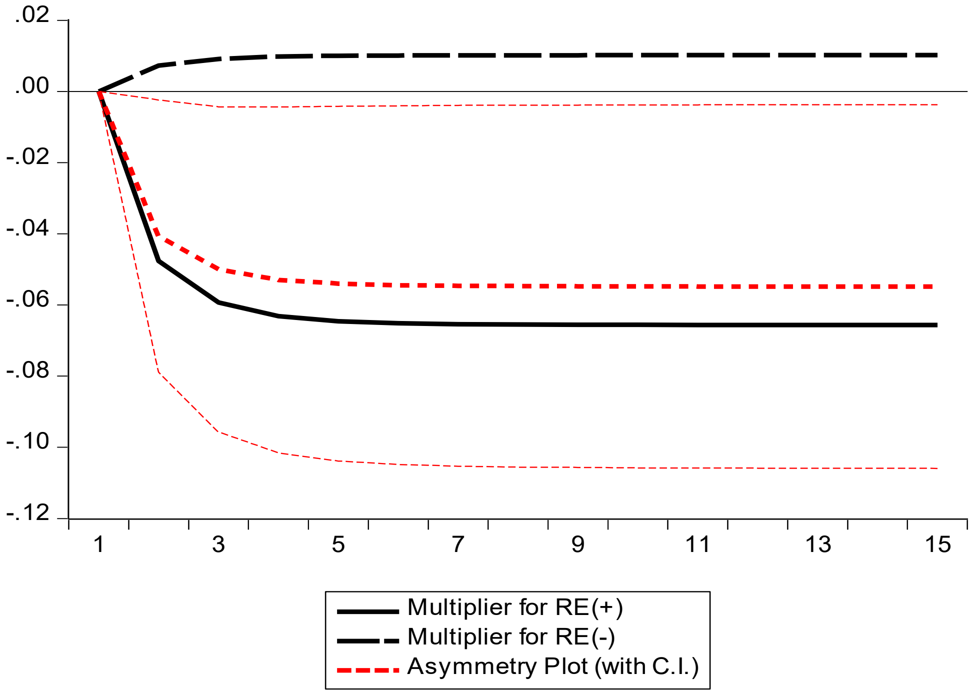


Figure 4.6: Dynamic multiple adjustments of Renewable Energy Consumption

4.5. Concluding Remarks and Policy Recommendations

This paper contributes to the knowledge by reconsidering whether the asymmetric effect is detected in the impacts of renewable energy consumption and globalization on the goal of carbon neutrality in South Africa over the period 1990 to 2018. To achieve this objective, we apply the Nonlinear ARDL model to capture the effects of the positive and negative shocks to economic growth, globalization, and renewable energy consumption on CO_2 emissions. The results suggest the presence of asymmetries among the variables employed.

CO_2 emissions respond differently to the positive and negative shocks to the explanatory variables both in the long run and short run. Specifically, economic growth responds positively to CO_2 emissions if the shock to economic growth is positive and negative if the shock to economic growth is negative. However, the effect of the negative shock is stronger. For globalization, its positive shock increases CO_2 emissions while the negative shock reduces CO_2 emissions with a stronger effect coming from a negative shock; although the effect of a negative shock is insignificant in the long run. Finally, we find that both the positive and negative shocks to renewable energy consumption have a decreasing effect on CO_2 emissions both in the long run and short run.

Based on these findings, the following policy implications are crafted: First, there is a need to stimulate the growth of renewable energy consumption by encouraging an influx of investments in renewable energy by public and private investors. In this case, policy instruments such as subsidies like tax credits, tax holidays, etc. could be used to encourage the influx of investments into the renewable energy sector of the economy.

Second, economic growth pursuit should be tailored towards green growth. In this case, boosting alternative clean energy consumption and investment should be the priority of policymakers in stimulating growth in the South African economy. What this means is that government has to ensure that necessary technologies are available to help improve production activities towards the path of pollution free. In this case, certain standards of pollution should be set. Firms that do not meet the standard should be taxed. Third, as much as globalization stimulates economic activity and increases income levels through the transfer of technological advancement, there is a need also to regulate the influx of firms so that their entrance would not constitute a channel of pollution.

To this extent, stringent environmental policies and taxes can be introduced to minimize the adverse effect of environmental pollution. Such policies should be aimed at promoting innovation in clean technologies and discouraging dirty technologies from being imported into the country. Also, policymakers should be careful in the use of environmental taxes so that domestic and foreign investors are not forced to relocate to other countries due to the high rate of environmental taxes. Notably, environmental taxes should be such that can partly reduce environmental degradation and can provide incentives for the use of cleaner energy. Therefore, this study is limited to South Africa's economy.

Future research can consider major economies in Africa to better understand the behaviors of environmental indicators in the continent of Africa. Moreover, since South Africa has implemented several strategies over the years to promote renewable energy and green growth, it is expected that such strategies will have an impact on environmental degradation. Therefore, future research should control for likely structural breaks associated with the trend of variables.

Chapter 5

SUMMARY AND CONCLUSION

The need for environmental quality improvement has attracted governments, academic, and policymakers over the years. This is borne out of the aggressive policies towards economic growth and development. Generally, as economies are transiting from one stage to another, so many variables would change. For example, energy consumption, level of globalization, democracy, etc. would increase. The increase of these variables may hurt the environment through emission of carbon dioxide with other components of green-house gases. Therefore, this research aims to examine dynamic effects of energy expansion, democracy, regulatory quality and globalization on the environment in South Africa.

In chapter 2, which follows the introductory chapter, I tested validity of Environmental Kuznet Curve (EKC) hypotheses for South Africa by incorporating the impact of globalization, energy utilization and democracy in South Africa. A flexible Auto-regressive Distributed Lag (ARDL) technique was adopted as estimation procedure for the study. The result shows the existence of EKC hypothesis for the long-run and the short-run in South Africa for the period covered. Increase in democracy and energy consumption stimulates environmental degradation while increase in globalization dampens environmental degradation.Causal relationship was found from CO_2 emission to economic expansion and democracy and globalization to energy utilization in the long-run, while in the short-run globalization and energy utilization causes CO_2emission. To check for the robustness of these findings innovation accounting tests were conducted and the results were validated.

In Chapter 3, therefore, I focused on testing the EKC hypothesis for South Africa by capturing impacts of structural break amongst other variables. In doing this I employed the minimum Langrange Multiplier (LM) unit root tests by Lee andStrazicich (2013.) to identify structural-breaks in the series. Structural break points were incorporated into the model to determine their effects on environmental degradation over the period covered. I found the EKC hypothesis in the existence of structural break. Globalization effect was weak in the short run. Although the break years identified were not statistically significant, also the causal relationship was found from every variable to environmental degradation in the long-run although short-run causality was detected from economic expansion to energy utilization to regulatory quality. I further found energy use to cause environmental degradation while globalization causes energy usage. The policy implication of the research is that stimulating globalization and strengthening regulatory quality would enhance environmental quality with maintaining a healthy EKC for South Africa.

Chapter 4 is a departed from existing literature by investigating whether the impacts of globalization, energy utilization, with economic expansion on environmental sustainability are characterized by directional asymmetries in South Africa. To this extent, I decomposed the variables into their positive and negative partial sums via the non-linear autoregressive distributed lag (NARDL) model, advanced by Shin et al. (2014). This idea is based on the failure of the linear assumption that environmental degradation reacts the same way to the positive and negative shocks to energy utilization, globalization, and economic expansion. The result shows that CO_2emission respond differently to the positive and negative shocks in the variables. The effect of a positive shock in economic growth is inelastic and positively related to CO_2 emissions while a negative shock in economic expansion has an elastic and negative effect on CO_2 emissions. These results hold for the long-run and short-run. For globalization, positive shock increases CO_2 emission while its negative shock decreases CO_2 emission in the long-run and short-run although the long-run impacts of a negative shock in globalization exerts an elastic negative effect on CO_2 emission compared to its short-run effect which exerts an inelastic negative effect. Furthermore, both the positive and negative shocks in renewable energy utilization have a negative effect on CO2 emission in the long-run and short-run. The paper provides insightful policy suggestions to enhance environmental sustainability in South Africa.

With respect to these findings, I therefore, recommend that energy and environmental policy makers to strengthen regulatory institutions and regulatory laws towards achieving environmental improvement in South Africa. This can be done by restructuring political and economic institutions by redefining the existing laws, establishing new laws pertaining to energy and environment as well as inculcating value reorientations among government agents and the citizens. Also, as the need to develop South Africa continues, decision-makers in government need to expand energy source to diminish its overdependence on coal consumption. In this case, to enhance the utilization of greener energy sources including solar, wind, biomass, hydroelectric power and nuclear power, the government should take proactive efforts so as to maintain a stable EKC for South Africa.

Furthermore, increasing the pace of globalization could combat the environmental effect of economic growth through technological advancements and technical know-how associated with the trend of globalization. Therefore, to optimally gain from globalization, I suggest the need to strengthen carbon tax, increase the supervision of energy-intensive activities, and ensure stringent compliance with carbon emissions laws to prevent the negative impact of globalization on the environment through the projected rapid increases in energy consumption. Finally, effort should be made by the policy makers to adopt laws that promote efficient use of energy in South Africa.

I also recommend that policymakers and stakeholders should pay adroit attention to reducing environmental degradation caused mainly by the utilization of fuel oil and other classical pattern of energy utilization. Specifically, the government of South Africa should impose taxes on carbon emissions, which is the surest way to reduce CO_2 emissions in countries with less stringent environmental laws. These taxes should be implemented in a manner that firms and industries will not shift production base from the country.

In addition, to accelerate growth, government should promote and stimulate democracy since causality runs from democracy to economic growth. Furthermore, policies that strengthen globalization should be pursued vigorously to accelerate growth and technological and technical know-how required to transform the economy into an industrialized one. Emphasis should be placed on the need to promote clean renewable energy like wind and wave, solar, hydropower, etc. because these kinds of energy generate lower levels of CO_2 emissions. Also, there is the need to stimulate the growth of sustainable and clean energy consumption by encouraging an influx of investments in renewable energy by the public and private investors.

Finally, economic growth pursuit should be tailored towards green growth. In this case, boosting alternative clean energy consumption and investment should be the priority of policymakers in stimulating growth in the South African economy. And also, as much as globalization stimulates economic activities and increases income levels through the transfer of technological advancement, there is a need also to regulate the influx of this transfer of technologies by the government and policymakers. This can be controlled by the imposition of carbon taxes and other taxes to discourage carbon-emitting firms from engaging in such activities that are causing environmental degradation.

5.2 Limitations of the study

This study has some limitations ranging from the dataset to the analysis. The first limitation is that the data used for the analysis stopped at 2016. To this extent, the analysis of this study cannot be used for policy making and formulation up-to-date given the dynamics of the South African economy. Second, given the international shocks created by the COVID-19 on the economy of South Africa and the world at large, it is clear that the policymakers have to be careful with the way and manner the results from this study could be applied for policy making. Third, this study is limited to South Africa; therefore, the behaviours of environmental indicators in South Africa could be quite different from other African countries. In this case, the results cannot be totally relied upon to design and formulate environmental policies for all African countries.

5.3 Suggestions for Future Research

Given the limitations of this study above, it is suggested that future studies should extend dataset to the present years. Moreover, such studies should cover particularly the period of COVID-19 pandemic, so that the way and manner environmental indicators react to the changes in economic and social variables in South Africa could be unveiled. Finally, it is suggested that future studies could apply panel data for Africa so that the results can be a guide for environmental policy making and formulation in Africa.

5.4 Contribution of the Study

This study contributed to the existing literature by providing a macroeconomic analysis of the effects of energy consumption, democracy, and globalization on environmental degradation in South Africa using econometrics tools thatare based on linear and nonlinear models.This study made three main contributions to the literature. First, the study revisited the EKC hypothesis for South Africa by incorporating not only the economic factors but also social and political factors. It is expected that economic variables alone are insufficient to explain the behaviours of environmental indicators. Second, the study contributed to the existing literature by incorporating the effect of structural breaks in a model of environmental degradation while testing for the EKC hypothesis in South Africa. Third, the study deviated from the linearity assumption by disentangling variables into their positive and negative shocks and examined their effects on environmental degradation in South Africa. This is believed that the positive shock in the explanatory variables may have different effect on environmental degradation from the negative shock of the same magnitude.

REFERENCES

Abid, M. (2016). Impact of economic, financial, and institutional factors on CO_2 emissions: Evidence from Sub-Saharan Africa economies. *Utilities Policy*, *41*, 85-94.

Aboagye S. (2017). Economic expansion and environmental sustainability nexus in Ghana. *African Development Review,* 29(2), 155-168.

Acemoglu, D., Johnson, S., & Robinson, J. A. (2002). Reversal of fortune: Geography and institutions in the making of the modern world income distribution. *The Quarterly Journal of Economics*, *117*(4), 1231-1294.

Acemoglu, D., Johnson, S., Robinson, J., &Thaicharoen, Y. (2003). Institutional causes, macroeconomic symptoms: Volatility, crises and growth. *Journal of Monetary Economics*, *50*(1), 49-123.

Adedoyin, F. F., Gumede, M. I., Bekun, F. V., Etokakpan, M. U., &Balsalobre-lorente, D. (2020). Modelling coal rent, economic growth and CO_2 emissions: Does regulatory quality matter in BRICS economies? *Science of the Total Environment*, *710*, 136284.

Adu, D. T., & Elisha, K. D. (2018). Economic growth and environmental pollution in West Africa: Testing the environmental kuznets curve hypothesis. *Kasetsart Journal of Social Sciences*.

Agbede, E. A., Bani, Y., Azman-Saini, W. N., & Naseem, N. A. (2021). The impact of energy consumption on environmental quality: Empirical evidence from the MINT countries. *Environmental Science and Pollution Research*, *28*(38), 54117-54136.

Ahmed, K., Bhattacharya, M., Qazi, A.Q., & Long, W. (2016). Energy consumption in China and underlying factors in a changing landscape: Empirical evidence since the reform period. *Renewable and Sustainable Energy Reviews,* 58, 224–234.

Akadiri, S. S., & Adebayo, T. S. (2021). Asymmetric nexus among financial globalization, non-renewable energy, renewable energy use, economic growth, and carbon emissions: Impact on environmental sustainability targets in India. *Environmental Science and Pollution Research*, 1-13.

Akadiri, S. S., Alkawfi, M. M., Uğural, S., &Akadiri, A. C. (2019). Towards achieving environmental sustainability target in Italy: The role of energy, real income and globalization. *Science of The Total Environment*, *671*, 1293-1301.

Akinlo A.E. (2009). Electricity consumption and economic growth in Nigeria: Evidence from cointegration and co-feature analysis. *Journal of Policy Modelling.* 31, 681-693.

Akpan, G. E., & Akpan, U. F. (2012). Electricity Consumption, carbon emissions and economic growth in Nigeria. *International Journal of Energy Economics and Policy*, 2(4), 292-306.

Alege, P. O., Jolaade, A., &Adu, O. (2018). Is there co-integration between renewable energy and economic growth in selected Sub-Saharan African counties? *International Journal of Energy Economics and Policy,* 8(4), 219-226.

Alhassan, A., &Alade, A. S. (2017). Income and democracy in Sub-Saharan Africa. *Journal of Economics and Sustainable Development,* 8(18), 67-73.

Alhassan, A., Usman O., Ike, G.N., &Sarkodie, S.A. (2020). Impact assessment of trade on environmental performance: Accounting for the role of government integrity and economic development in 79 countries. *Heliyon,* 6(9) e05046.

Ali A., Usman, M., Usman, O., & Sarkodie, S.A (2021) Modeling the effects of agricultural innovation and biocapacity on carbon dioxide emissions in an agrarian-based economy: Evidence from the dynamic ARDL Simulations. *Frontiers inEnergy Research*, 8:592061

Al-Mulali U., Saboori B., & Ozturk I. (2015). Investigating the Environmental Kuznets Curve Hypothesis in Vietnam. *Energy Policy,* 76, 123-131.

Alola, A. A., Akadiri, S. S., & Usman, O. (2021). Domestic Material Consumption and Greenhouse Gas Emissions in EU-28 Countries: Implications for Environmental Sustainability Targets, *Sustainable Development,* 29(2), 388-397.

Alola, A. A., Yalçiner, K., Alola, U. V., & Saint Akadiri, S. (2019). The role of renewable energy, immigration and real income in environmental sustainability target: Evidence from Europe largest states. *Science of the Total Environment,* 674, 307–315.

Andrew, R.M., & Peters, G. P. (2021). The global carbon project's fossil cO2 emissions dataset [Data set]. Zenodo. https://doi.org/10.5281/zenodo.5569235.

Antweiler, W., Copeland, B. R., & Taylor, M. S. (2001). Is free trade good for the environment? *American Economic Review*, *91*(4), 877-908.

Apergis N., & Ozturk I. (2015). Testing environmental kuznets curve hypothesis in Asian countries. *Ecological Indicators,* 52, 16-22.

Apergis, N., & Payne, J. E. (2009). CO_2 emissions, energy usage, and output in Central America. *Energy Policy*, *37*(8), 3282-3286.

Apergis, N., & Payne, J. E. (2009). Energy consumption and economic growth in Central America: Evidence from a panel cointegration and error correction model. *Energy Economics*, *31*(2), 211-216.

Apergis, N., & Payne, J. E. (2010). The emissions, energy consumption, and growth nexus: Evidence from the commonwealth of independent states. *Energy Policy*, *38*(1), 650-655.

Apergis, N., Jebli, M. B., & Youssef, S. B. (2018). Does renewable energy consumption and health expenditures decrease carbon dioxide emissions? Evidence for sub-Saharan Africa countries. *Renewable Energy,* 127: 1011-1016.

Apergis, N., Payne, J. E., Menyah, K., &Wolde-Rufael, Y. (2010). On the causal dynamics between emissions, nuclear energy, renewable energy, and economic growth. *Ecological Economics,* 69(11), 2255-2260.

Asghari, M. (2013). Does FDI promote MENA region's environment quality? Pollution halo or pollution haven hypothesis. *Int J Sci Res Environ Sci*, *1*(6), 92-100.

Baek, J., Cho, Y., & Koo, W. W. (2009). The environmental consequences of globalization: A country-specific time-series analysis. *Ecological Economics*, 68(8-9), 2255-2264.

Balcilar, M., & Usman, O. (2021). Exchange rate and oil price pass-through to inflation in BRICS countries: Evidence from the spillover index and rolling-sample analysis.*Energy,* 229, 120666.

Balcilar, M., Beyene, A., Gupta, R., &Seleteng M. (2013). 'Ripple' effects in South African house prices. *Urban Studies,* 50(5), 876-894.

Balcilar, M., Roubaud, D., Usman, O., &Wohar, M. E. (2021a). Testing the asymmetric effects of exchange rate pass-through in BRICS countries: Does the state of the economy matter? *The World Economy,* 44(1), 188-233.

Balcilar, M., Roubaud, D., Usman, O., &Wohar, M. E. (2021b). Moving out of the linear rut: A period-specific and regime-dependent exchange rate and oil price pass-through in BRICS countries. *Energy Economics* 98(2), 105249.

Banerjee, A., Dolado J., & Mestre, R. (1998) Error-correction mechanism tests for cointegration in a single-equation framework. *Journal of Time Series Analysis,* 19(3), 267-283.

Barrett, S., &Graddy, K. (2000). Freedom, growth, and the environment. *Environment and Development Economics,* 5(4), 433-56.

Bayer, C., &Hanck C. (2013). Combining non-cointegration tests. *Journal of Time Series Analysis*, 34(1), 83-95.

Bekun, F. V., Alola, A. A., & Sarkodie, S. A. (2019). Toward a sustainable environment: Nexus between CO_2 emissions, resource rent, renewable and nonrenewable energy in 16-EU countries. *Science of the Total Environment*, *657*, 1023-1029.

Ben Jebli, M., Ben Youssef, S., &Apergis, N., (2015). The dynamic interaction between combustible renewables and waste consumption and international tourism: The case of Tunisia. *Environmental Science Pollution and Research*, 22, 12050–12061

Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from top 38 countries. *Applied Energy,* 162, 733–741.

Black, W. R. (2010). *Sustainable Transportation: Problems and Solutions*. Guilford Press.

Bokpin, G. A. (2017). Foreign direct investment and environmental sustainability in Africa: The role of institutions and governance. *Research in International Business and Finance*, *39*, 239-247.

Boswijk H. P. (1994). Testing for an unstable root in conditional and unconditional error correction models. *Journal of Econometrics,* 63, 37-60.

Brock, W. A., Dechert, W. D. &Scheinkman. J. A. (1987). A test for independence based on the correlation dimension. Working Paper, University of Wisconsin, University of Houston, and University of Chicago.

Chandia K. E, Gul, I., Aziz, S., Sarwar, B., & Zulfiqar, S. (2018). An analysis of the association among carbon dioxide emissions, energy consumption and economic performance: An econometric model. *Carbon Management*, 1-15.

Chen, S., Saud, S., Bano, S., & Haseeb, A. (2019). The nexus between financial development, globalization, and environmental degradation: Fresh evidence from Central and Eastern European Countries. *Environmental Science and Pollution Research*, *26*(24), 24733-24747.

Chintrakarn, P.,&Millimet, D. (2006). The environmental consequences of trade: Evidence from sub-national trade flows. *Journal of Environmental Economics and Management,* 52, 430–453.

Choi, E., Heshmati, A., & Cho, Y. (2010). An Empirical Study of the Relationship between CO_2 Emissions. *Economic Growth and Openness*, IZA DP No-5304.

Christmann, P., &Taylor, G. (2001). Globalization and the environment: Determinants of firm self-regulation in China. *Journal of International Business Studies,* 32, 439-458.

Cole, M. A. (2004). Trade, the pollution haven hypothesis and the environmental Kuznets curve: Examining the linkages. *Ecological Economics*, *48*(1), 71-81.

Cole, M. A. (2006). Does trade liberalization increase energy use? *Economics Letters,* 92, 108–112.

Cole, M. A., Elliott, R. J., & Fredriksson, P. G. (2006). Endogenous pollution havens: Does FDI influence environmental regulations? *Scandinavian Journal of Economics*, *108*(1), 157-178.

Copeland, B. R. & Taylor, M. S. (1994). North-South trade and the environment. *Quarterly Journal of Economics,* 109 (3), 755–787.

Copeland, B. R. (2005). Policy endogeneity and the effects of trade on the environment. *Agricultural and Resource Economics Review*, 34, 1–15.

Copeland, B. R. (2013). Trade and the Environment. In *Palgrave Handbook of International Trade* (pp. 423-496). Palgrave Macmillan, London.

Copeland, B. R., & Taylor, M. (2004). Trade, growth and the environment. *Journal of Economic Literature,* 42(1), 7–71.

Dean, J. (2002). Does trade liberalization harm the environment? A new test. *Canadian Journal of Economics*, 35 (4), 819–842.

Dean, J. M. (1992). Trade and the Environment: A Survey of the Literature (No. 966). The World Bank.

Dedeoğlu, D., & Kaya, H. (2013). Energy use, exports, imports and GDP: New evidence from the OECD countries. *Energy Policy*, *57*, 469-476.

Dinda, S. (2006). Globalization and environment: Can pollution haven hypothesis alone explain the impact of globalization on environment? MPRA Paper No. 50590.

Dogan, E. & Ozturk, I. (2017). The influence of renewable and non-renewable energy consumption and real income on CO_2 emissions in the USA: Evidence from structural break tests. *Environmental Science and Pollution Research,* 24, 10846-10854.

Dogan, E., &Seker, F. (2016). Determinants of CO_2 emissions in the European Union: The role of renewable and non-renewable energy. *Renewable Energy*, 94, 429-439.

Dong, L., Ren, J., Rodrigues, J. F., &Tukker, A. (2017). The socioeconomic and environmental impacts of fossil fuels subsidies reduction and renewable energy expansion in China. *Environmental and Economic Impacts of Decarbonization: Input-Output Studies on the Consequences of the 2015 Paris Agreements*, 341.

Dreher, A. (2006). Does globalization affect growth? Evidence from a new index of globalization. *Applied Economics*, *38*(10), 1091-1110.

Dudka, S., & Adriano, D. C. (1997). Environmental impacts of metal ore mining and processing: A review. *Journal of Environmental Quality*, *26*(3), 590-602.

Ehigiamusoe, K. U., & Dogan, E. (2022). The role of interaction effect between renewable energy consumption and real income in carbon emissions: Evidence from low-income countries. *Renewable and Sustainable Energy Reviews*, *154*, 111883.

Engle, R.F., &Granger, C. (1987). Cointegration and error correction representation: Estimation and testing. *Econometrica,* 55, 251-276.

Esso L.J. (2010). Threshold cointegration and causality relationship between energy use and growth in seven African countries. *Energy Economics.* 32, 1383-1391 (2010).

Farzin, Y.H., &Bond, C.A. (2006). Democracy and environmental quality. *Journal of Development Economics, 81*(1), 213-235.

Fisher R. (1932). *Statistical Methods for Research Workers*. London: Oliver and Boyd.

Fredriksson, P. G., &Svensson, J. (2003). Political instability, corruption and policy formation: The case of environmental policy. *Journal of Public Economics*, *87*(7-8), 1383-1405.

Friedman, T. (2005). *The World is Flat: A Brief History of the Twenty-First Century*. New York, NY: Farrar, Straus and Giroux.

Galinato, G. I., & Chouinard, H. H. (2018). Strategic interaction and institutional quality determinants of environmental regulations. *Resource and Energy Economics*, *53*, 114-132.

Gokmenoglu K., &Taspinar, N. (2015). The relationship between industrial production, GDP, inflation and oil price: The case of Tukey, *Procedia Economics and Finance,* 25, 497-503.

Gökmenoğlu, K., & N. Taspinar (2016). The relationship between CO_2emissions, energy consumption, economic growth and FDI: The Case of Turkey. *The Journal of International Trade & Economic Development,* 25(5), 706-723.

Gozgor, G., Mahalik, M. K., Demir, E., &Padhan, H. (2020). The impact of economic globalization on renewable energy in the OECD countries. *Energy Policy*, *139*, 111365.

Grossman, G. M., & Krueger, A. B. (1991). Environmental impacts of a North American free trade agreement (No. W3914). National Bureau of Economic Research.

Grossman, G. M., & Krueger, A. B. (1995). Economic growth and the environment. *The Quarterly Journal of Economics*, *110*(2), 353-377.

Grossman, G. M., & Krueger, A. B. (1996). The inverted-U: What does it mean? *Environment and Development Economics*, *1*(1), 119-122.

Gungor, H., Abu-Goodman, M., Olanipekun, I. O., &Usman O. (2021b). Testing the environmental Kuznets curve with structural breaks: The role of globalization, energy use, and regulatory quality in South Africa, *Environmental Science and Pollution Research*, 28 (4), 1-12

Güngör, H., Olanipekun, I. O., & Usman, O. (2020). Testing the environmental Kuznets curve hypothesis: The role of energy consumption and democratic accountability. *Environmental Science and Pollution Research*, 1-15

Gungor, H., Olanipekun, I. O., and Usman O. (2021a). Testing the Environmental Kuznets Curve Hypothesis: The role of Energy Consumption and Democratic Accountability, *Environmental Science and Pollution Research*, 28, 1464-1478

Halicioglu, F. (2009). An econometric study of CO_2 emissions, energy consumption, income and foreign trade in Turkey. *Energy Policy*, *37*(3), 1156-1164.

Harrison, A. E., &Eskeland, G. (1997). *Moving to greener pastures? Multinationals and the pollution-haven hypothesis*. The World Bank.

He, J. (2006). Pollution haven hypothesis and environmental impacts of foreign direct investment: The case of industrial emission of sulfur dioxide (SO_2) in Chinese provinces. *Ecological Economics*, *60*(1), 228-245.

Heilbronner R.L. (1974). *An Inquiry into the Human Prospect*, New York: Norton.

Hoffmann, R., Lee, C. G., Ramasamy, B., & Yeung, M. (2005). FDI and pollution: A granger causality test using panel data. *Journal of the Development Studies Association*, *17*(3), 311-317.

Hu P., Li Y., Zhang X., Guo Z., & Zhang P. (2008). CO_2 emission from container glass in China, and emission reduction strategy analysis.*Carbon Management,* 1-8.

Hubbard, R., & O'Brien, A. (2013). *Economics* 4th ed. New Jersey: Pearson International Edition.

Ibrahim, M. D., &Alola, A. A. (2020). Integrated analysis of energy-economic development environmental sustainability nexus: Case study of MENA countries. *Science of The Total Environment*, 139768.

Ike, G. N., Usman, O., Alola, A. A., & Sarkodie, S. A. (2020a). Environmental quality effects of income, energy prices, and trade: The role of renewable energy consumption in G-7 countries. *Science of The Total Environment*, 721, 137813.

Ike, G.N., Usman, O., &Sarkodie, S. A. (2020a). Fiscal policy and CO_2 emissions from heterogeneous fuel sources in Thailand: Evidence from multiple structural breaks cointegration test. *Science of the Total Environment* 702: 134711.

Ike, N.G., Usman O., & Sarkodie, S. A. (2020b). Testing the role of oil production in the Environmental Kuznets Curve of oil producing countries: New insights from method of moments quantile regression, *Science of the Total Environment*, 711, 135208.

Inglesi-Lotz, R., &Bohlmann, J. (2014). Environmental Kuznets curve in South Africa: To confirm or not to confirm? *EcoMod*(No. 6378).

International Energy Agency, IEA (2019). Key world energy statistics. Available online at: https://www.iea.org/statistics/kwes/prices/. Retrieved 18 July 2019.

International Energy Agency. (2010). World Energy Outlook 2010 Report. Available online at: https://www.iea.org/newsroom/news/2010/november/world-energy-outlook-2010.html (Accessed on 11 August, 2014).

Iorember, P. T., Gbaka, S., Jelilov, G., Alymkulova, N., & Usman, O. (2022). Impact of international trade, energy consumption and income on environmental degradation in Africa's OPEC member countries. *African Development Review*, 34(2), 175-187.

Iorember, P. T., Goshit, G. G., &Dabwor, D. T. (2020b). Testing the nexus between renewable energy consumption and environmental quality in Nigeria: The role of broad-based financial development. *African Development Review*, *32*(2), 163-175.

Iorember, P. T., Jelilov, G., Usman, O., Işık, A., &Celik, B. (2020a). The influence of renewable energy use, human capital, and trade on environmental quality in South Africa: Multiple structural breaks cointegration approach. *Environmental Science and Pollution Research*, 1-13.

Iwayemi A. (1988). Energy sector development in Africa. Background paper for the 1998 African Development Report. *African Development Bank*.

Jalil, A., & Mahmud, S. F. (2009). Environment Kuznets curve for CO_2 emissions: A cointegration analysis for China. *Energy Policy*, *37*(12), 5167-5172.

Jebli, M. B., & Youssef, S. B. (2015). The environmental Kuznets curve, economic growth, renewable and non-renewable energy, and trade in Tunisia. *Renewable and Sustainable Energy Reviews.* 47, 173-185.

Jebli, M., Youssef, S., &Apergis, N. (2015). The dynamic interaction between combustible renewables and waste consumption and international tourism: The case of Tunisia. *Environmental Science Pollution and Research*, 22, 12050-12061

Jena, P. R., & Grote, U. (2008). Growth-trade-environment nexus in India. *Economic Bulletin*, 17 (11), 1-11.

Johansen, S. A (1995). Statistical analysis of cointegration for I(2) variables.*Econometric Theory*, 11, 25-59.

Kahia, M., Aïssa, M. S. B., &Lanouar, C. (2017). Renewable and non-renewable energy use-economic growth nexus: The case of MENA net oil importing countries. *Renewable and Sustainable Energy Reviews*, 71, 127-140.

Katircioglu S. T., &Katircioglu S. (2018). Testing the role of urban development in conventional environmental Kuznets curve: Evidence from Turkey. *Applied Economics Letters*, 25, 741-746.

Katircioglu, S. T. (2014). International tourism, energy consumption, and environmental pollution: The case of Turkey. *Renewable and Sustainable Energy Reviews*, *36*, 180-187.

Katircioglu, S. T., Feridun, M., &Kilinc, C. (2014). Estimating tourism-induced energy consumption and CO_2 emissions: The case of Cyprus. *Renewable and Sustainable Energy Reviews,* 29, 634-640.

Lee, K. H., & Min, B. (2014). Globalization and carbon constrained global economy: A fad or a trend? *Journal of Asia-Pacific Business*, 15, 105-121.

Ling, C. H., Ahmed, K., Muhamad, R. B. & Shahbaz, M. (2015). Decomposing the trade environment nexus for Malaysia: What do the technique, scale, composition, and comparative advantage effect indicate? *Environmental Science and Pollution Research,* 22, 20131-20142.

Liu, M., Ren, X., Cheng, C., & Wang, Z. (2020). The role of globalization in CO_2 emissions: A semi-parametric panel data analysis for G7. *Science of The Total Environment*, *718*, 137379.

Lopez, R. (1994). The environment as a factor of production: The effects of economic growth and trade liberalization. *Journal of Environmental Economics and Management*, *27*(2), 163-184.

Löschel, A., Rexhäuser, S. &Schymura, M. (2013). Trade and the environment: An application of the WIOD database. *Chinese Journal of Population Resources and Environment,* 11, 51-61.

Lucas, R. E. B., Wheeler, D., &Hettige, H. (1992). Economic development, environmental regulation and the international migration of toxic industrial pollution: 1960–1988. In Low, P. (Ed.), *International Trade and the Environment*, World Bank Discussion Paper No. 159.

Lv Z. (2017).The effect of democracy on CO_2 emissions in emerging countries: Does the level of income matter? *Renewable and Sustainable Energy Reviews,* 72, 900-906.

Maji I. B. (2015). Does clean energy contribute to economic growth? Evidence from Nigeria. *Energy Reports,* 1, 145–150.

Managi, S., Hibiki, A., & Tetsuya, T. (2008). Does trade liberalization reduce pollution emissions? Discussion Papers 08013, Research Institute of Economy, Trade and Industry (RIETI).

Menyah, K., &Wolde-Rufael, Y. (2010). Energy consumption, pollutant emissions and economic growth in South Africa. *Energy Economics.* 32, 1374–1382.

Mesagan, E. P., Isola, W. A., &Ajide, K. B. (2018). The Capital investment channel of environmental improvement: Evidence from BRICS. *Environment, Development, and Sustainability,* 1-22.

Midlarsky, M. I. (1998). Democracy and the environment: An empirical assessment, *Journal of Peace Research,* 35(3), 341-361.

Mineral Resources and Energy Department (2021). Energy Resource Guide, 2021 Edition. Available online at:http://www.energy.gov.za/files/renewables_frame.html.

Moutinho, V., Varum C., &Madaleno, M. (2017). How economic growth affects emissions? An investigation of the environmental Kuznets curve in Portuguese and Spanish economic activity sectors.*Energy Policy,* 106, 326–344.

Musa, M. S., Jelilov, G., Iorember, P. T., & Usman, O. (2021). Effects of tourism, financial development, and renewable energy on environmental performance in EU-28: Does institutional quality matter? *Environmental Science and Pollution Research*, 28(5), 53328–53339.

Nasr, A. B., Gupta, R., & Sato, J. R. (2015). Is there an Environmental Kuznets Curve for South Africa? A Co-summability Approach using a century of data. *Energy Economics,* 52, 136-141.

Nentjes, A., de Vries, F. P., & Wiersma, D. (2007). Technology-forcing through environmental regulation. *European Journal of Political Economy*, *23*(4), 903-916.

Okafor, H.O. (2012). Testing the relationship between energy consumption and economic growth: Evidence from Nigeria and South Africa. *Journal of Economics and Sustainable Development.* 3(11), 111-124.

Olanipekun, I. O., Olasehinde-Williams, G. O., &Alao, R. O. (2019). Agriculture and environmental degradation in Africa: The role of income. *Science of The Total Environment*, *692*, 60-67.

Omotor D.G. (2008). Causality between energy consumption and economic growth in Nigeria: *Pakistan Journal of Social Sciences,* 5(8), 827 -835.

Omri A. (2013). CO_2 emissions, energy consumption and economic growth nexus in MENA countries: Evidence from simultaneous equations models.*Energy Economics,* 40, 657-664.

Ozatac, N., Gokmenoglu K. K., &Taspinar, N. (2017). Testing the EKC hypothesis by considering trade openness, urbanization, and financial development: The case of Turkey. *Environmental Science and Pollution Research,* 24(20), 16690-16701.

Ozturk, I., &Acaravci, A. (2013). The long-run and causal analysis of energy, growth, openness and financial development on carbon emissions in Turkey. *Energy Economics.* 36, 262-267.

Panayotou, T. (1997). Demystifying the environmental kuznets curve: Turning a black box into a policy tool. *Environment and Development Economics*, 2: 383-399.

Panayotou, T. (2000). Population and environment. *CID* Working Paper Series No.2000.53. Harvard University, Cambridge.

Pao, H.T., & Fu, H.C. (2013). Renewable energy, non-renewable energy and economic growth in Brazil.*Renewable and Sustainable Energy Reviews,* 25, 381-392.

Pao, H. T., & Tsai, C. M. (2010). CO_2 emissions, energy consumption and economic growth in BRIC countries. *Energy Policy,* 38(12), 7850-7860.

Paramati, S. R., Alam, M. S., Hammoudeh, S., & Hafeez, K. (2021). Long-run relationship between R&D investment and environmental sustainability: Evidence from the European Union member countries. *International Journal of Finance & Economics*, 26(4), 5775-5792.

Paramati, S. R., Sinha, A., & Dogan, E. (2017). The significance of renewable energy use for economic output and environmental protection: Evidence from the

Next 11 developing economies. *Environmental Science and Pollution Research*, *24*(15), 13546-13560.

Paramati, S.R., Apergis, N. &Ummalla, M. (2017). Financing clean energy projects through domestic and foreign capital: The role of political cooperation among the EU, the G20 and OECD countries.*Energy Economics,* 61, 62-71.

Payne R.A. (1995). Freedom and the environment. *Journal of Democracy*, 6(3), 41-55.

Pesaran, M. H., Shin, Y., & Smith, R. J. (2001). Bounds testing approaches to the analysis of level relationships. *Journal of Applied Econometrics,* 16, 289-326.

Phillips, P. C. B., and Hansen, B. E. (1990): Statistical inference in instrumental variables regressions with I(1) processes. *Review of Economic Studies,* 57, 99-125.

Rafindadi, A. A., & Usman, O. (2019). Globalization, energy use, and environmental degradation in South Africa: Startling empirical evidence from the Maki-cointegration test. *Journal of Environmental Management*, *244*, 265-275.

Rafindadi, A. A., & Usman, O. (2021). Toward sustainable electricity consumption in Brazil: The role of economic growth, globalization and ecological footprint using a nonlinear ARDL approach. *Journal of Environmental Planning and Management*, *64*(5), 905-929.

Rahman, H. U., Zaman, U., & Górecki, J. (2021). The role of energy consumption, economic growth and globalization in environmental degradation: Empirical evidence from the brics region. *Sustainability*, *13*(4), 1924.

Raza, S. A., Sharif, A., Wong, W. K., & Karim, M. Z. A. (2017). Tourism development and environmental degradation in the United States: Evidence from wavelet-based analysis. *Current Issues in Tourism*, *20*(16), 1768-1790.

Rodrik, D. (2008). *One Economics, Many Recipes: Globalization, Institutions, and Economic Growth*. Princeton University Press.

Rondinelli, D., & Berry, M. (2000). Multimodal transportation, logistics, and the environment: Managing interactions in a global economy. *European Management Journal*, *18*(4), 398-410.

Sambo A.S. (2008). Energy Demand and Supply Projections in Nigeria: Paper presented at the 1st IEEA/NAEE Conference, Sheraton Hotel, Abuja.

Samimi, A. J., Ahmadpour, M., & Ghaderi, S. (2012). Governance and environmental degradation in MENA region. *Procedia-Social and Behavioral Sciences*, *62*, 503-507.

Scruggs, L.A. (1998). Political and economic inequality and the environment. *Ecological Economics*, *26*(3), 259-275.

Shafiei, S., & Salim, R. A. (2014). Non-renewable and renewable energy consumption and CO_2 emissions in OECD countries: A comparative analysis. *Energy Policy*, 66, 547-556.

Shahbaz M., Khan S., Ali A., & Bhattacharya M. (2017a). The impact of globalization on CO_2 emissions in China. *The Singapore Economic Review,* 62(4): 929-957.

Shahbaz, M. (2019). Globalization-Emissions Nexus: Testing the EKC hypothesis in Next-11 Countries. Available online at: https://mpra.ub.uni-muenchen.de/93959/MPRA Paper No. 93959, posted 21 May 2019.

Shahbaz, M., Bhattacharya, M., & Ahmed, A. (2017c). CO_2 emissions in Australia: Economic and non-economic drivers in the long-run. *Applied Economics,* 49 (13), 1273-1286.

Shahbaz, M., Dube, S., Ozturk, I., & Jalil, A. (2015). Testing the environmental Kuznets curve hypothesis in Portugal. *International Journal of Energy Economics and Policy.* 5(2), 475-481.

Shahbaz, M., Lean, H. H., & Shabbir, M. S. (2010). Environmental Kuznets Curve and the role of energy consumption in Pakistan. Discussion Paper DEVDP 10/05, Development Research Unit, Monash University, Australia.

Shahbaz, M., Mahalik, M. K., Shahzad, S. J. H., &Hammoudeh, S. (2019). Testing the globalization-driven carbon emissions hypothesis: International evidence. *International Economics*, *158*, 25-38.

Shahbaz, M., Mallick, H., Mahalik, M. K., & Loganathan, N. (2015). Does globalization impede environmental quality in India? *Ecological Indicators*, *52*, 379-393.

Shahbaz, M., Mutascu, M., & Azim, P. (2013b) Environmental Kuznets curve in Romania and the role of energy consumption. *Renewable and Sustainable Energy Reviews*, 18, 165-173.

Shahbaz, M., Nasreen, N., Ahmed, K., &Hammoudeh, S. (2017b). Trade openness–carbon emissions nexus: The importance of turning points of trade openness for country panels. *Energy Economics,* 61, 221-232.

Shahbaz, M., Nasreen, S., Abbas, F., & Anis, O. (2015). Does foreign direct investment impede environmental quality in high-, middle-, and low-income countries? *Energy Economics*, *51*, 275-287.

Shahbaz, M., Ozturk, I., Afza, T., & Ali, A. (2013a). Revisiting the environmental Kuznets curve in a global economy. *Renewable and Sustainable Energy Reviews*, 25, 494-502.

Shahbaz, M., Shahzad, S. J. H., Alam, S., &Apergis, N. (2018). Globalization, economic growth and energy consumption in the BRICS region: The importance of asymmetries. *The Journal of International Trade & Economic Development*, *27*(8), 985-1009.

Shahbaz, M., Solarin, S. A., & Ozturk, I. (2016). Environmental Kuznets curve hypothesis and the role of globalization in selected African countries. *Ecological Indicators*, *67*, 623-636.

Shahbaz, M., Solarin, S. A., Hammoudeh, S., & Shahzad, S. J. H. (2017b). Bounds testing approach to analyzing the environment Kuznets curve hypothesis with structural beaks: The role of biomass energy consumption in the United States.*Energy Economics* 68 (2017) 548-565.

Shahbaz, M., Van Hoang, T. H., Mahalik, M. K., &Roubaud, D. (2017c). Energy consumption, financial development and economic growth in India: New evidence from a nonlinear and asymmetric analysis. *Energy Economics*, *63*, 199-212.

Sharif, A., Godil, D. I., Xu, B., Sinha, A., Khan, S. A. R., &Jermsittiparsert, K. (2020). Revisiting the role of tourism and globalization in environmental degradation in China: Fresh insights from the quantile ARDL approach. *Journal of Cleaner Production*, *272*, 122906.

Shin, S. (2004). Economic globalization and the environment in China: A Comparative case study of Shenyang and Dalian. *The Journal of Environment Development,* 13, 263-294.

Shin, Y., Yu, B., & Greenwood-Nimmo, M., (2014). Modelling asymmetric cointegration and dynamic multipliers in an ARDL framework. InHorrace, W.C., &Sickles, R.C. (Eds.), *Festschrift in Honour of Peter Schmidt*, New York: Springer Science and Business Media.

Silva, S., Soares, I., &Pinho, C. (2012). The impact of renewable energy sources on economic growth and CO_2 emissions: A SVAR approach. *European Research Studies, Special Issue on Energy,* 15(1), 133-144.

Soytas, U., Sari, R., & Ewing, B. T. (2007). Energy consumption, income, and carbon emissions in the United States. *Ecological Economics*, *62*(3-4), 482-489.

Stern D. (2003). The Environmental Kuznets Curve. *International Society for Ecological Economics,* 2267-3472.

Stern, D. I. (2004). The rise and fall of the environmental Kuznets curve. *World Development*, *32*(8), 1419-1439.

Stern, D. I. (2007). The effect of NAFTA on energy and environmental efficiency in Mexico. *Policy Studies Journal*, *35*(2), 291-322.

Stern, D. I., Common, M. S., &Barbier, E. B. (1996). Economic growth and environmental degradation: The environmental kuznets curve and sustainable development. *World Development*, *24*(7), 1151-1160.

Taylor, M. S. (2005). Unbundling the pollution haven hypothesis. *The BE Journal of economic Analysis & Policy*, *4*(2).

Torras, M., & Boyce, J. K. (1998). Income, inequality, and pollution: A reassessment of the environmental Kuznets curve. *Ecological Economics,* 25(2), 147-160.

Trébuil, G. (1995). Pioneer agriculture, green revolution and environmental degradation in Thailand. *Counting the costs: Economic Growth and Environmental Change in Thailand*, 67-89.

Ulucak, Z. Ş., İlkay, S. Ç., Özcan, B., &Gedikli, A. (2020). Financial globalization and environmental degradation nexus: evidence from emerging economies. *Resources Policy*, *67*, 101698.

Usman, O., Akadiri, S. S. &Adeshola, I. (2020b). Role of renewable energy and globalization on ecological footprint in the USA: Implications for environmental sustainability. *Environ Science and Pollution Research* 27, 30681–30693.

Usman, O., Alola, A. A., & Sarkodie, S. A. (2020d). Assessment of the role of renewable energy consumption and trade policy on environmental degradation using innovation accounting: Evidence from the US. *Renewable Energy*, *150*, 266-277.

Usman, O., Bekun, F. V., & Ike, G. N. (2020c). Democracy and tourism demand in European countries: does environmental performance matter? *Environmental Science and Pollution Research*, *27*(30), 38353-38359.

Usman, O., Iorember, P. T., &Olanipekun, I. O. (2019). Revisiting the environmental kuznets curve (EKC) hypothesis in India: The effects of energy consumption and democracy. Environmental Science and Pollution Research, 26(13), 13390–13400.

Usman, O., Olanipekun, I. O., Iorember, P. T., & Abu-Goodman, M. (2020a). Modelling environmental degradation in South Africa: The effects of energy consumption, democracy, and globalization using innovation accounting tests. *Environmental Science and Pollution Research*, 27:8334–8349.

Usman O.(2020). Does the pass-through of exchange rate and globalization validate the rockets and feathers hypothesis in Nigeria? Evidence from a Nonlinear Model.*Journal of Public Affairs,* 21 (1), e2151

Usman, O. (2022). Modelling the economic and social issues related to environmental quality in Nigeria: The role of economic growth and internal conflict". *Environmental Science and Pollution Research*, 29 (27), 39209-39227.

Usman, O.,Alola, A.A., &Akadiri, S.S. (2022) Effects of domestic material consumption, renewable energy, and financial development on environmental sustainability in the EU-28: Evidence from GMM panel-VAR.*Renewable Energy*, 184, 239-251.

Usman, O., &Elsalih, O. (2018). Testing the effects of real exchange rate pass-through to unemployment in Brazil. *Economies,* 6(3) 49, 1-13.

Wijen, F. & Van Tulder, R. (2011). Integrating environmental and international strategies in a world of regulatory turbulence. *California Management Review*, 53(4), 23-46.

Woods, W. I. (2004). Population nucleation, intensive agriculture, and environmental degradation: The Cahokia example. *Agriculture and Human Values*, *21*(2-3), 255-261.

World Bank. (2018). World Development Indicators. Retrieved from. http://data.worldbank.org/country. (Accessed on 11 August, 2018).

You, W.H., Zhu, H.M., Yu, K.M., & Peng, C. (2015). Democracy, financial openness, and global carbon dioxide emissions: Heterogeneity across existing emission levels. *World Development*, 266:189-207.

Zaghdoudi T. (2017). Oil prices, renewable energy, CO_2 emissions and economic growth in OECD countries. *Economics Bulletin,* 37(3), 1844-1850.

Zakaria Z. (2017). CO_2 emissions, renewable energy and the environmental kuznets curve: A panel cointegration approach. *Renewable and Sustainable Energy Reviews,* 72, 1067–1075.

Zhang, X. P., & Cheng, X. M. (2009). Energy consumption, carbon emissions, and economic growth in China. *Ecological Economics*, *68*(10), 2706-2712.