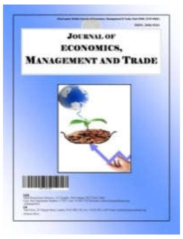

Journal of Economics, Management and Trade

26(11): 38-53, 2020; Article no.JEMT.63086
ISSN: 2456-9216
(Past name: British Journal of Economics, Management & Trade, Past ISSN: 2278-098X)

The Role of Demographic Transition, Technological Innovation on Environmental Degradation in the Congo Basin

Ebai Rascobi Akololos Nguambi[1*], Ngouhouo Ibrahim[1] and ZonyinObertine Nkwenti[1]

[1]The Dschang School of Economics and Management, The University of Dschang, Cameroon.

Authors' contributions

This work was carried out in collaboration among all authors. All authors duly participated in writing this work. Author ERAN designed the study with the help of author NI. Authors ERAN and ZON scrutinized the background and the review of previous literature and performed the statistical analysis, while author ERAN wrote the first draft of the manuscript which was read and corrected by author NI. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JEMT/2020/v26i1130311
Editor(s):
(1) Alfredo Jimenez Palmero, University of Burgos, Spain.
Reviewers:
(1) Casmir Chidiebere Onyeneke, Hezekiah University, Nigeria.
(2) Israel Patino Galvan, Tecnológico de Estudios Superiores de Ecatepec, Mexico.
Complete Peer review History: http://www.sdiarticle4.com/review-history/63086

Original Research Article

Received 15 September 2020
Accepted 17 November 2020
Published 31 December 2020

ABSTRACT

Ensuring Environmental sustainability as a means of stimulating growth remains an issue of great concern. In the past decades the environment has been deteriorating and almost every part of the planet has been touched. The main cause of environmental degradation is linked to humans' activities such as agricultural intensification, population growth and energy consumption. Demographic transition entails many challenges as the population decreases due to a fall in birth rate and high dependency ratio, the technological progress usually improve health care and standard of living thereby increasing the life expectancies. The objective of this paper is therefore to investigate whether excess demography and technological innovation can explain the environmental degradation in the Countries that make up the Congo Basin. By applying the panel ARDL model (PMG), we realized that the demographic variables (Life Expectancy and depending ratio) negatively influence the environmental degradation**.** We equally found that technological innovation significantly reduces environmental emissions. However, the results do not support the hypothesis

**Corresponding author: E-mail: ebairascobi@gmail.com;*

of the Environmental Kuznets Curve (EKC) for most of the countries except for Gabon and the Republic of Congo. Finally this region through policy implementation has to make greater efforts in controlling demographic change and new technologies that are environmentally friendly.

Keywords: Technological innovation; CO_2 emissions; Environmental Kuznets Curve; panel ARDL model (PMG).

1. INTRODUCTION

Environmental degradation is seen as the most preoccupying issue on earth today especially in the less developing countries. The environment provides mankind with a wide range of economic, social and environmental benefits. However, these environments are increasingly being threatened as a result of man's activities in trying to acquire from the nature what they need for their daily survival. Economic activity promotes wealth creation but has negative effects on the environment. The production systems currently used in most countries generate vastquantities of waste and contamination, causing degradation to natural resources. These impacts are more severe when accompanied by demographic growth, as long as population increases it lead to increases in energy consumption and, consequently, to greater atmospheric pollution. The absence of sustainable use of natural resources is due to land use change in favour of agriculture, specifically industry-driven agriculture [1,2]. Other authors, mostly conservationists point out the population growth (overpopulation) or demographic pressures also known as Malthusians theories. However, the rapid rate of environmental degradation and the loss of bio-diversities is one of the world's most prominent environmental concerns.

Efforts around the world are focused on achieving sustainable environmental management since the 1992 United Nations (UN) declaration (Rio de Janeiro), The result of these efforts is the fact that the legal policy on the environment is improving in many countries around the world particularly in Central Africa, as evidenced by political commitment at the highest level, by the development of national and regional programmes for the environment throughout the sub regions, and by progressive new legislation in many countries. Regional partnerships also provide a solid framework for appropriate action. However, the protection of the environment remains far below what is required; the capacity to enforce laws and to implement programmes effectively remains weak in many countries. Consequently, in most tropical countries, an environmental management policy has been implemented insufficiently. FAO [1] reported that during the years from 1995 to 2005, Africa lost more than 9% of its natural resources especially its forest area. This situation is more critical in Central Africa, where the extraction volumes of natural resources exceed production. It is feared that if nothing is done to check this problem, the resources will soon disappear.Until now there have been crucial limitations in the design of environmental management plans and their implementation. The reasons for this are related both to the insufficient planning techniques and the surrounding environment such as enormous diversity of resources, socio-economic conditions and the inadequate institutional and legal framework. In this context, there is a need for developing a simple and practical environmental management planning system that could be easily implemented and represents a useful sustainable environmental management tool.

According to the Intergovernmental Group of Experts on the Evolution of Climate (GIEC), the acceleration of environmental pollution is mainly due to human factors (agriculture, demographic growth, deforestation, industrialization, trade) (GIEC, 2007, 2013). Therefore, the analyses of the impact of these variables on environmental degradation has become a very important issue in economic literature and an important number of studies seek to check the hypothesis of Environmental Kuznets Curve (EKC) between economic growth and the indicators of environmental degradation [3,4] etc. The importance of the EKC is based in the fact that, if the standard of living of the individuals improves, the possibility for poor countries of improving environmental quality as they develop is guaranteed, that is, there is growing support for environmental consciousness (World Bank, 1992). Empirically, many authors have done a detailed review on the relationship between economic growth and environmental quality [5,6]. The diversity of studies confirms the fact that environmental problems differ from one region to another, giving rise to the need for solutions specific to each region in order to limit the environmental disaster.

a) **Demographic Transition and Environmental Degradation:** According to the theory of the Demographic Transition (DT) the evolution of population goes through three phases.[1] Initially, when income is low and the economy is in a preindustrial state, both birth and death rates are high: cultural reasons and no birth control measures keep birth rates high while the plight of people and little progress in medical science keep death rates high. Population growth is consequently low. As incomes grow the situation improves. In the second phase, industrial phase, while death rates decline birth rates remain initially high, so that population growth is strong. In the final phase, as per capita incomes further increase, both rates are reduced and population growth slows down. These considerations lead to represent population growth vis-à-vis per capita income by means of an inverted-U shape, like a "Demographic Kuznets Curve" (DKC) [7,8].

Looking at the current positioning of the world population, the data show that more than 50% of world population lies in the second phase of the demographic transition and at a stage of the ecological transition where per capita incomes are still low. From a sustainability point of view the problem is how to take most of the world population to higher income levels without causing deep environmental degradation. The implications for policy here are apparent. It remains, however, as a preliminary step to understand which and how important the interrelations between demographic transition and environmental degradation are, the implications one has for the other, possibly adopting a regional perspective, typically between rich and poor countries. A second important aspect to recall is that inverted-U EKCs may not hold for all pollutants and that the evidence in this respect is mixed. This holds in principle also for the demographic transition. A third caveat refers to the fact the EKCs are in general effective ways to summarize ex-post correlations, but they cannot be used to draw policy implications such as, say, unconditional and accelerated economic growth. Analogous considerations could be made for unconditional population growth.

Recent research suggests that rapidly growing population not only increases pressure on marginal lands, over-exploitation of soils, overgrazing, over cutting of wood, soil erosion, silting, flooding but also increases excess use of pesticides, fertilizers, causing land degradation and water pollution. They further, stated that this rapidly growing population influence in three ways, first contribution relate to industrial production and energy consumption resulting in carbon dioxide emission (CO_2) from the use of fossil fuel, second land-use changes such as deforestation affect the exchange of CO_2 between earth and the atmosphere, and third agricultural process such as land cultivation and live-stock are responsible for the greenhouse gasses in the atmosphere. According to their estimate, population growth accounts for 35 percent of greenhouse gasses in the atmosphere. Population growth adds to the amount of greenhouse gases emitting into the atmosphere in many ways. With increasing deforestation, agricultural and industrial production, each of the activities requires the burning of fossil fuels and/or increases the emissions of gases like carbon dioxide, methane. Some researchers estimated that 0.4-2.6GtC of carbon dioxide were released into the atmosphere due to change in the pattern of land use [9,10], and 95 percent of this amount was due to deforestation in the tropical rain forests areas. More than one third of the increase in the atmospheric carbon dioxide is due to depleting of land forests. A study carried out empirically found a relationship between population growth and natural resources in the United States [11] and stated that the composition and scale of activities in the United States are changing chemistry of the nation's land, water and atmosphere so dramatically that some of these changes are adversely affecting its natural capital and thus, the ecosystem services are required to support its population.

b) **Technological Innovation and Environmental Degradation:** This paper equally examines the technology dimension in achieving a sustainable economy and analyzes or looks at the possibilities of modifying or revising our basic technologies of production, and consumption and of existing products and processes. Technological innovations have considerable

[1] *This theory was originally expounded by the French demographer Landry in 1934.*

effects on the association among economic entities. This is manifested in Schumpeter (1942)'s notion of "Creative Destruction", which is an evolutionary process involving the destruction of the inefficient and weak sectors of the economy as well as development of new technologies and new industries [12]. By the same token, technological innovations have environmental consequences. It is logical to argue that a technological innovation leading to structural changes in production process shall also influence the environment. Technology is an important channel through which economic growth impacts environmental degradation [3]. Due to this impact, a number of studies have urged employing technologies which can improve environmental quality [5]. Progress leads to the creation of cleaner and ecologically sustainable technologies (Hussen, 2005). This profound importance of the technological process is manifested in the argument which states "When the total effect of the relationship between economic growth and environmental pollution is dissected, the technical effect is the main factor in environmental pollution reduction" [13]. Motivated by the importance of technology in environmental degradation a number of empirical studies analyze the nexus between the two factors. For instance, a study carried out in 2013 reports a significant relationship between electricity consumption, economic growth, and technological innovations. [2] It showed that technological innovations play an important role in mitigating the use of fossil fuels [14]. These findings are complemented by a later study [15] which also confirms the importance of technological innovation to environmental degradation in New Zealand and Norway. In a similar vein, a number of other studies also reflect the importance of technology in mitigating environmental degradation and ecological challenges [16,17,18,19]. The importance of technological factors in mitigating environmental degradation also implies that efforts shall be made to avoid the obsolescence of technology, which is very often done via regulation of technological development [20]; and [19]. However, one under-appreciated aspect of this which has profound implications for policy-making is investment in energy innovations. It is intuitively acknowledged and evident by earlier cited studies that innovation in general, are important for environmental degradation, and therefore, innovations in the energy sector would have rather direct implications.

In the context of the technological development critique, in the 1960s Lucas and Romer developed a new thesis denominated *New Growth Theory,* which states the importance of takinginto consideration the concept of *induced innovation,* defined as the 'impact of economic activityand policy on research, development and the diffusion of new technologies' [21]. Basic and applied research can be used to improve the level of knowledge of a society, which will result into an improvement of the efficiency in the use of environmental resources. Investing in research will prove very profitable for a society especially in the long run: while it is necessary to face a high cost at the beginning, as the inventive activity develops, improvements will reduce the costs of environmental control. In this way new knowledge is created, and also knowledge which already exists is spread across firms (Weizsäcker, 1966). Many scientists believe that the new technologies may play a fundamental role in trying to solve today's environmental problems. In the long run the induced innovation approach will prove more efficient than the substitution approach caused by the price mechanism [21]. In the developing countries, it is important to remember that often their economic structure is characterized by insufficient investment, innovation and human capital leading to a non-homogeneous spread of technological achievements [22]. According to the data gathered by the World Bank, in the timeframe that goes from 2006 to 2012, OECD countries have spent on average 2,36% of their GDP on R&D, as opposed to the 1,09% average spent by Low Income countries. Considering the different magnitudes of GDPs of the two groups of countries, it is clear that the under-developed countries cannot solely count ontechnological development in order to improve their environmental condition.

Although some estimation can be made regarding the beneficial impact that newtechnologies will have on the

[2] *This is the manifestation of the applicability of endogenous growth theory to the energy sector.*

environment, the actual path that their development will take is stilluncertain. An opposing thought to the *technological optimism* which believes that technologies will eliminate resources and energy limits to growth is that of *technological pessimism*. "Humanity has the ability to make development sustainable to ensure that it meets the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limitations imposed by the present state of technology and social organization on environmental resources and by the ability of the biosphere to absorb the effects of human activities[3]".This concept is linked to a more general definition of sustainable development that implies that a development path in order to be sustainable has to grant the maintenance or the increase of the capital assets over time and throughout generations [23].

The innovative element introduced by the World Commission is the consideration given to the environmental factor. The recognition of the existence of relative limits implies that the current generation does not have to care only about the preservation of the manufactured capital, but also of the environmental or natural capital, without which even the manufactured capital could not be preserved or developed. This observation does not imply that today's society has to choose either the imposition of limits to growth or the unrestricted economic growth, but suggests the need of adopting a more comprehensive view of the performance of today's economic systems. In order to do so, it is fundamental to grant equal distribution of resources in present and future generations. Most often, natural resources and environmental costs are not equally distributed among countries. In particular, the Environmental Kuznets Curve describes the relation that exists between income and environmental deterioration, claiming that at low levels of income the latter tends to increase. According to World Bank's data, in 2014 the rate of depletion of natural resources (forest, energy and minerals) was nearly 6 times higher in low and middle income countries if compared to the rate of OECD countries. Similarly, the population-weighted exposure to air pollution was 2.5 times higher in low and middle income countries than in OECD countries. Moreover, environmental degradation is more regressive in poor and emerging countries. Policies of redistribution of wealth and technologies together with the implementation of environmental regulations can help the underdeveloped world to escape the trap of non-sustainability. Because of the transversal and global nature of environmental degradation, assuring a universal and homogeneous adoption of high environmental standards and sustainable resource depletion is necessary in order to assure the preservation of environmental capital throughout time.

It is worth mentioning the fact that, although in the First and Second Industrial Revolutions the technological improvement has had a negative impact on the exhaustion of the Earth's capacity by accelerating the exhaustion of resources and by emitting into the environment a high quantity of waste, today many scholars argue that if properly redirected, technological change could reduce the impact of economic activities and improve the future environmental situation. However, even if technologies might expand the Earth's carrying capacity, there still exists a *biophysical carrying capacity,* namely "the maximum demographic size that an area can sustain under given technological capabilities" [24], which merely constitutes an upper bound on carrying capacity.

Meanwhile the process of technological change proceeds through three stages. Schumpeter (1942) described this process as one of ''creative destruction.'' First, an idea must be born. This stage is known as invention. New ideas are then developed into commercially viable products. This stage is called innovation. Often, these two stages of technological change are studied together under the rubric of research and development (R&D). Finally, for an innovation to have an effect on the economy, individuals must choose to make use of the new innovation. This stageis known as diffusion. At each stage, incentives, in the form of prices or regulations, will affectthe development and adoption of new technologies.

[3]*World Commission on Environment and Development [23], p. 4*

At all three stages of the technological change process, market forces provide insufficientincentives for investment in environmentally friendly technologies. Economists point totwo market failures as the causes of the resulting underinvestment in environmental R&D. It is these market failures that motivate government policy aimed at increasing R&D on environmentally friendly technologies.

- The first market failure is the traditional problem of *environmental externalities*. Because carbon emissions are not priced by the market, firms and consumers have no incentive to reduce emissions without policy intervention. Moreover, because carbon emissions are a global externality, the damages depend on the sum of emissions across all countries. Thus, where emissions reductions occur is not as important as whether they occur. Without appropriate policy interventions, the market for technologies that reduce emissions will be limited, thus reducing incentives to develop such technologies. However, even if this market failure is not addressed through government policy, there may still be some incentives to develop technologies that reduce carbon emissions because such technologies may also provide private benefits. However, the market failure problem means that individuals do not consider the social benefits of using technologies that reduce emissions.
- The second market failure pertaining to environmental Development is *the public goods nature of knowledge* [25]. In most cases, new technologies must be made available to the public for the inventor to reap the rewards of invention. However, when this happens, some (if not all) of the knowledge embodied in the invention also becomes available to the public. This public knowledge may lead to additional innovations or even to copies of current innovations.[4] These knowledge spillovers benefit the public as a whole but not the innovator. This means it is nearly impossible for the firm transferring a technology to be fully compensated for the enhanced productivity the recipient will enjoy when employing the technology in future projects. As a result, private firms do not have incentives to provide the socially optimal level of research activity, and climate-friendly development will be underprovided by market forces even if policies to correct the environmental externalities of emissions, such as carbon taxes are in place. As a result this paper therefore seeks to investigate whether Excess Demography and Technological Innovation explain the Environmental Degradation.

Many researchers argue that the obstacles to the proper allocation of costs are the main cause of environmental degradation. These obstacles may originate from an imperfect information regarding resources or due to an artificial distortion of prices through subsidies for many environmentally destructive services and technologies (World Bank, 1992). This viewpoint is sometimes categorized as the "neoclassical political economy" perspective. There is another middle perspective which argues that improper use of technology is the main cause of environmental degradation. According to this perspective rapid demographic increases can worsen the problems created by the improper use of technology.

Although the growing concern about the role of population growth and technological change in environmental degradation is a relatively recent phenomenon, the study of the population-resources (especially food) relationship is not new. [26]. As early as the late 18th century, Thomas Malthus laid the foundation for a theory of population-resource inter relationships by saying that, over the long run population and resources remain in a state of equilibrium mediated by the available technology of food production and the prevailing living standard.

However, some researchers presented the EKC and that the two phases can be explained by three effects of development on the environment [3]: the scale, composition and technique effects. To understand this mechanism, we use the decomposition of total emissions proposed by Grossman and Krueger [3], and Antweiler et al. [27]:

[4] *Intellectual property rights, such as patents, are designed to protect inventors from such copies. However, the effectiveness of property rights varies depending on the ease with which inventors may "invent around" them by making minor modifications to an invention. See, for example, Levin et al. (1987).*

$$\widehat{D} = \hat{y} + \sum_{i=1}^{n} \pi_i \, \hat{a}_i + \sum_{i=1}^{n} \pi_i \, \hat{s}_i$$

Where $\widehat{D}$ represents the total reduction in resources or total emissions caused by the *n* sectors of the economy, $\hat{a}_i$is the intensity of the reduction, i.e. the average quantity of resources reduced for each unit of output in the sector *i,* $\hat{s}_i$ represents the weight of sector *i* in thenational product, π_i is the share of reduction by sector *i* in the total reduction and $\hat{y}$the national income which is often the GDP and captures the size of the economy of a given country i. This decomposition brings out three structural effects:

- Scale Effect: The scale effect refers to the increase in environmental nuisances following increases in production. Assuming that the state of technology and the structure of the economy remain unchanged, any increase in production will result in an increase in environmental nuisances of the same amount. Here, $\hat{y}$ denotes the scale effect which summarizes the fact that if the technology and the structure of production remain unchanged, that is to say if $\boldsymbol{\hat{a}_i}$ = ***0***and$\boldsymbol{\hat{s}_i}$ = **0** then:$\boldsymbol{\widehat{D}} = \boldsymbol{\hat{y}}$: this therefore implies an increase in economic activity is accompanied by an increase in the degradation of the resource. Economic growth and the respect of the environment are thus incompatible [6].

- Composition Effect: The composition effect captures the effect of a change in the structure of production on the environment. The structural transformation witnessed by developed countries i.e. the passage from a primarily agricultural economy to an industrial economy resulted in a rise in the intensity of pollution, the level of technology remaining unchanged. This effect is related to international specialization. In order to separate this effect, we assume that $\boldsymbol{\hat{y}}$**= 0** and $\boldsymbol{\hat{a}_i}$ ***= 0,*** which enables us to write:

$$\boldsymbol{\widehat{D} = \sum_{i=1}^{n} \pi_i \hat{s}_i}$$

- Technique Effect: The technique effect refers to the invention of new environmental friendly technologies in production which in turn leads to the reduction of pollutants.In other words it captures the impact of technical progress on environmental quality. Thus, any improvement of the technical coefficients will result in a deceleration of the rate of increase of environmental degradation. Moreover, the installation of rigorous environmental regulation, due to environmental consciousness will also enable a reduction of environmental degradation. The technique effect takes into account the variation of the level of degradation per unit of good produced. Here we suppose here that $\boldsymbol{\hat{y}}$**= 0** and $\boldsymbol{\hat{s}_i}$ **= 0** that is to say economic activity and the structure of production are fixed. In this case, we have:

$$\boldsymbol{\widehat{D} = \sum_{i=1}^{n} \pi_i \hat{a}_i}$$

Consequently, if $\boldsymbol{\hat{a}_i}$**< 0**, that is to say if the techniques of production become cleaner,degradation per monetary unit of production drops and the technique effect leads to areduction in the destruction of the environment. The overall impact of GDP on the environment depends on which effect is stronger and dominates the others.

A study made by Yao, Feng (2014) to determine the main driving forces of CO_2emissionin the G20 countries (which includes South Africa) using the IPAT framework for the period1971-1990 indicates that, unlike China, South Korea, Brazil, Turkey and Australia whose main driver for CO_2 emission was economic growth, South Africa's main driver of CO_2 emission was due to high population growth which was estimated to be around 25% for that period. Economic structure and energy intensity improvement was an important contributor for reduction in CO_2 emission for South Africa (7% reduction in emission) like the rest of the G20 countries for the same period of time. However the period 1990-2010 showed that the contribution of population growth became much smaller and further forecasts indicates that population growth as the major driving factor would be replaced by other drivers of emission in decades after 2010.

Dietz and Rosa (1997) developed a modified form of the IPAT model called STIRPAT model (Stochastic Impacts by Regression onPopulation, Affluence, and Technology) and they estimated the effect of population and affluence on CO_2 emissions using a multiple regression on 111 nations for the year 1989. They first estimated the general additive model which converts the basic STIRPAT model in logarithmic form. They also modified the model into a polynomial which included the quadratic form in the log of population and cubic form in the log of population form to allow for non linearities and provide adequate parametric match to the non-parametric characteristics of the variables. Their estimation result of their log-linearized model indicates that a 1.15% growth of population leads to one percent increase in CO_2 at a global level. Moreover, around 1.08% growth in affluence leads to a 1% growth in CO_2 emission levels. Affluence is represented by growth of domestic product per capita.

The relationship between population and economic growth have been examined for Nigeria using the data from 1980 to 2010, specially focusing on the effects of fertility and infantmortality rates on the economic growth. The method of estimation was Vector Auto Regressive(VAR) econometric techniques. The results showed that decrease in fertility rate increasedeconomic growth rate gradually from 3.3% to 7.9% for horizon of 12 years during the period ofthe study. Also, an increase in infant mortality rate increased economic growth rate from 0.6% to 15.9% for same time horizon (Olabiyi, 2014).

The use of CO_2 emissions as proxy for environmental degradation poses a problem of relevance according some authors; however the use of this variable as proxy of air pollution could be justified in various ways:

- ✓ Firstly, CO_2 is the principal greenhouse gas responsible for the climate change; its regulation thus becomes a very important intergovernmental question (Talukdar & Meisner, 2001). Such a study will lead to the proposal of a plan of convergence of the CO_2 emissions for countries of the Congo Basin;
- ✓ Moreover, the data bases on CO_2 emissions are accessible, unlike the other indicators for which there only exists very little data, especially as concerns the countries targeted by this study.

Fig. 1 shows the evolution of CO_2 in the different countries of the Congo basin from 1985 to 2014. Here we see that, CO_2 in Cameroon, DRC and Gabon initially drops in 1985 and started increasing in 1987 and eventually drops considerably from 1988-2014. But the rate of CO_2 reduction in DRC is greater as compared to that of Cameroon and Gabon. Meanwhile, in the Republic of Congo we find a fluctuating trend of emissions with time but in CAR it first of all increases from 1985 and drops almost in constant rate. Lastly, Equatorial Guinea portrays a contrary situation in which CO_2 emissions remain slightly above zero rates from 1985-2000 after which it increases before dropping from 2004.

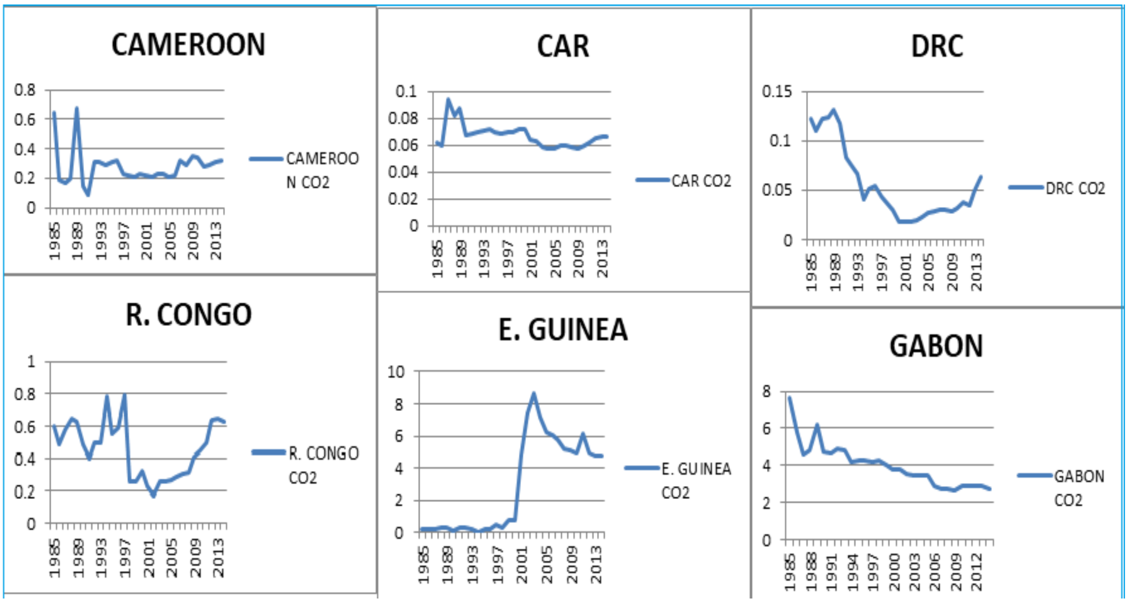

Fig. 1. Evolution of CO_2 Emissions in Metric Tons per Capita from 1985 to 2014
CAR and DRC represent Central Africa Republic and Democratic Republic of Congo respectively.
Source: Author using data from WDI 2020

2. METHODOLOGY

In this section, we present the tools (giving statistical variables of analysis, econometric model and technique of estimates) which permit us to verify whether excess demography and technological innovation explain the environmental degradation in the Congo Basin.

2.1 The Econometric Model

For an empirical validation of the above ideas, data for various dimensions of demography, technology, and environment are needed. The methodological approach is based on the CO_2 equation below in which the explanatory variables are selected from the a variety of literatures

$$C0_2 = \beta_1 + \beta_2 Demo + \beta_3 Tech + \beta_4 M + \varepsilon \quad (1)$$

Where

$\boldsymbol{CO_2}$ is carbon dioxide emission which measures the quality of the environment,*Demo* is a matric of demographic characteristics such as dependency ratio and life expectancy, *Tech* is technological innovation which is measured by industry value added (INDVA) this variable capture the effect of industrial activities on the environment. *M* is a matrix of other control variables such as: Trade Openness (TROPEN), several studies demonstrate a correlation between international trade and the deterioration of the environment in low-income countries, Gross Domestic Product per capita (GDP), Foreign Direct Investment (FDI) and Final Consumption Expenditure (FCE) and ε is the error term.

These indicators are obtained from World Development Indicators (WDI 2020) and the work takes into account data of each variable over the period of 1985-2018. In it log-linear form, equation (1) can therefore be written explicitly as follows:

$$InCO_{2t} = \beta_0 + \beta_i lnDemo_t + \beta_i lnTech_t + \beta_i lnM_t + \varepsilon_t \quad (2)$$

2.2 Estimation Technique

Numerous studies have used Engle and Granger (1987) and Johansen and Juselius(1991) and Johansen (1991) techniques to test the co-integration between economic variables. These techniques oblige that all regressors in the system must be stationary with the same order of integration. Pesaran et al. (2001) has developed a model to introduce a delegate co-integration technique known as ARDL bound testing approach which has many advantages over the previous co-integration techniques (Pesaran et al., 2001; Ghatak and Siddiki, 2001; Jayaraman and Choong, 2009; Ozturk and Acaravci, 2011; Bekhet and Al-Smadi, 2015):

First, no need to examine the non-stationary property and order of integration. This means that we can apply ARDL whether underlying regressors are purely I(0) or purely I(1), while other co-integration techniques require all the regressors to be integrated of the same order, and secondly, the ARDL model has become increasingly popular in recent years. Based on these advantages, this paper employed a panel ARDL model or Pooled Mean Group (PMG) estimation [28], which takes into account I(0) and I(1) series. To examine the co-integration among the variables (Equation 1), the ARDL approach is derived from the unrestricted error correction model and formulated for each variable as follows:

$$\Delta CO_{2it} = \emptyset_0 \left(CO_{2i,t-1} - \beta_i X_{i,t-1} \right) + \sum_{j=1}^{p-1} \lambda_{ij} CO_{2i,t-j} + \sum_{j=0}^{q-1} CO_{2i,j} X_{i,t-j} + \mu_i + \mu_{ij} \quad (3)$$

Where, CO_{2it} is the scalar-dependent variable (Carbon dioxide emissions); X_{it} is the *k* x 1 vector of regressors (demographic and technological innovation variables and other explanatory variables) for country *i;* $\mu_i$represents the country specific effects; $\emptyset_i$ is the scalar coefficient on the dependent variable; β_i is the *k* x 1 vector of coefficients on explanatory variables; λ_{ij} are scalar coefficients of the first difference of dependent variables and $Y_{i,j}$ are the *k* x 1 coefficient vector on the firstdifference of explanatory variables.

Equation (3) can therefore be rewritten as the vector error correction model (VECM) as follows:

$$\Delta CO_{2it} = \emptyset_0 \eta_{i,t-1} + \sum_{j=1}^{p-1} \lambda_{ij} \Delta CO_{2i,t-1} + \sum_{j=0}^{q-1} CO_{2i,j} \Delta X_{i,t-j} + \mu_i + \mu_{ij} \quad (4)$$

Where $\boldsymbol{\eta_{i,t-1}}$ is the error correction term; $\emptyset_i$ is the error correction coefficient measuring the speed of adjustment.

3. RESULTS

3.1 Stationarity Test

To verify the stationarity of the variables, we have made used of the Im-Pesaran-Shin test in order to be certain that the variables are integrated of order 0 and or 1, that is to say I(0) and or I(1) as seen in Table 1.

3.2 Panel Cointegration Tests

Table 2 represents the result of Koa cointegration test (See appendix 1, Pedroni cointegration test). These tests or results significantly reject the null hypothesis of the absence of cointegration at 1% level except forAugmented Dickey-Fuller t for the Koa cointegration test.Therefore,it can be confirmed that the variables in our equation move together especially in the long run. This is to say, after allowing for country specific effects, there is a relationship between the variables used in the study and that demography and technological innovation explain or affect environmental degradation in the Congo basin Countries. Our next step will therefore be to estimate the magnitude of such variables on environmental degradation by using the panel ARDL technique.

The objective of this paper is to analysewhether Excess Demography and Technological Innovation explain the Environmental Degradation in the Countries of the Congo basin. This objective is examined using the results in Tables 3 and 4 which enables us to study the variables retained in our study according to their significance. The results gotten using the PMG method suggest that there is a strong positive relationship among life expectancy (i.e. LEXP) and CO_2 in the long run. The magnitude of the LEXP coefficient which is positive and significant at 1% threshold is approximately 0.36.

In the short run the coefficient of life expectancy and dependency ratio shows that if growth in life expectancy or dependency ratio rises, the environmental degradation decrease in most of the countries in the Congo basin except for DRC and Gabon in which LEXP and DEPR respectively show a positive relationship. The result of the regression analysis has affirmed that the current demographic change slows down environmental degradation in most of the countries. The coefficients of the demographic variables evidently show the negative impact that life expectancy and total dependency ratio have on environmental degradation. This result is shared by Marie-LorSundman who studied 'the effects of the demographic transition on economic growth: Implications for Japan'.

Table 1. The Im-Pesaran-Shin stationarity test

Variables	Im-Pesaran-Shin								Decision
	Level				Difference				
	Constant		Constant + Trend		Constant		Constant + Trend		
	Stat	P. Value	Stat	P. Value	Stat	P. Value	Stat	P. Value	
CO_2	-1.9399	0.0262	-3.2706	0.0005	-11.6543	0.0000	-10.7569	0.0000	I(0)
INDVA	-1.0193	0.1540	-0.5458	0.2926	-7.0846	0.0000	-5.4495	0.0000	I(1)
GDPC	1.4899	0.9319	1.6046	0.9457	-7.4107	0.0000	-6.3117	0.0000	I(1)
GDPC2	1.4749	0.9299	1.5531	0.9398	-8.2212	0.0000	-7.2825	0.0000	I(1)
TROPEN	-0.0957	0.4619	0.2652	0.6046	-8.4441	0.0000	-7.2573	0.0000	I(0)
DEPR	-1.8573	0.0316	-0.4579	0.3235	-1.7901	0.0367	0.8046	0.7895	I(0)
POG	-11.6522	0.0000	-12.6725	0.0000	-11.7521	0.0000	-11.2609	0.0000	I(0)
FDI	-0.7220	0.2351	-1.4476	0.0739	-11.1861	0.0000	-10.0398	0.0000	I(1)
FCE	-2.5873	0.0048	-2.6559	0.0040	-11.6437	0.0000	-11.1760	0.0000	I(0)
LEXP	-10.2562	0.0000	-22.2567	0.0000	-10.8572	0.0000	-17.9993	0.0000	I(0)

Note: I(1) and I(0) signifies stationary at first difference and at level respectively

Table 2. Results from Kao Cointegration Test

	Statistics	P. Value
Modified Dickey-Fuller t	-5.1364	0.0000
Dickey-Fuller t	-5.4575	0.0000
Augmented Dickey-Fuller t	-0.6469	0.2588
Unadjusted modified Dickey-Fuller t	-9.0156	0.0000
Unadjusted Dickey-Fuller t	-6.3712	0.0000

Table 3.Demographic transitions and environmental degradation panel ARDL estimation

Model 1, dependent variable: LCO2. PMG estimation										
Model 1	**Constant**	**LEXPR**			**LDEPR**			**LPOG**		
Country	**Coefficient**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**
Cameroon	-1.802647	-.2502761	.1202281	0.037 **	-.1171455	.0436838	0.007**	1.464863	1.153001	0.204
CAR	-.0637413	-.0016303	.0029085	0.575	-.001457	.0027816	0.600	-.0188829	.009304	0.042**
DRC	.0115013	.0270542	.0110078	0.014**	-.0004052	.0079526	0.959	.0248059	.0128575	0.054 *
E. Guinea	5.235179	-12.73921	6.530748	0.051*	-.4363219	.4005886	0.276	.6096394	1.307917	0.641
Gabon	1.671483	-.9290437	.214861	0.000***	.6443219	.1525665	0.000***	3.160535	.9008992	0.000***
R. Congo	-1.509298	-.2360391	.0786049	0.003***	.0022851	.0780362	0.977	.0726937	.2203747	0.742

ECT|
LEXP |Coefficient.0364428Std. Err. .0056608P>|z|0.000***

*Note: ***, **, * represent 1%, 5% and 10% respectively,CAR and DRC represent Central Africa Republic and Democratic Republic of Congo respectively*

Table 4.Technological innovation and environmental degradation panel ARDL estimation

Model 2, dependent variable: LCO2. PMG estimation										
Model 2	**Constant**	**LINDVA**			**LTROPEN**			**LFDI**		
Country	**Coefficient**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**
Cameroon	2.821007	-1.270957	.7686519	0.098*	-.0447787	.1689065	0.791	.0377764	.018349	0.040**
CAR	.5395692	-2.839513	.	.	.1090683	.2106782	0.605	.0107504	.0240706	0.655
DRC	-.5772908	-2.530064	1.45202	0.081*	.5366059	.1412514	0.000***	-.1721376	.0503365	0.001***
E. Guinea	-.2462173	.2424387	.1806138	0.179	-.5840557	.0533344	0.000***	.0635549	.0084435	0.000***
Gabon	1.371291	-.3124665	.1024948	0.002***	-.1432563	.152693	0.348	-.0107348	.0074982	0.152
R. Congo	.9927919	-.4867563	.2077899	0.019**	.3395605	.1238733	0.006***	-.0337367	.0083951	0.000***

ECT |
LINDVA | Coefficient**.4370344 Coef. Std. Err .1922074 P>|z| 0.023 ****

Table 5.Quadratic EKC specification panel ARDL estimation

Model 2, dependent variable: LCO2. PMG estimation										
Model 3	**Constant**		**LGDPC**			**LGDPC2**			**LFDI**	
Country	**Coefficient**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**	**Coefficient**	**Std.Err**	**P-Value**
Cameroon	.1381979	3.788911	7.867131	0.630	-.2696964	.5644116	0.633	.0455432	.0217559	0.036**
CAR	-.3184362	-1.110576	4.699127	0.813	.0772666	.3926855	0.844	.0266715	.0243921	0.274
DRC	-1.068792	-4.181412	3.76503	0.267	.3871272	.3475531	0.265	-.1674823	.0507853	0.001***
E. Guinea	-.0327421	-.2245368	1.533107	0.884	.053057	.099269	0.593	.0975865	.0862704	0.258
Gabon	.3046583	6.50045	2.034044	0.001***	-.3588916	.1106689	0.001***	-.0117973	.0063611	0.064*
R. Congo	.2363599	2.848663	1.121247	0.011**	-.2131914	.0755113	0.005***	-.0320911	.0067576	0.000***

ECT |
loggppc | Coefficient Std. Err P>|z|
.0293794 .0151483 0.052*

The population growth also has been a main contributor to the quality of the environment in the region. The coefficient of Population growth (POG) is positive and significant in Gabon and DRC and negatively significant for CAR. The result of the regression analysis has affirmed that the current demographic change slows down environmental degradation. The coefficients of the demographic variables evidently show the negative impact that life expectancy and total dependency ratio have on environmental degradation.

Looking at the results in Table 4, we realized that technological innovation (INDVA) is positive and significant in the long run. It suggests that there is a strong positive relationship between technological innovation and environmental degradation in the long run. This relationship is explained by the magnitude of the coefficient of INDVA which is roughly 44% at 5 percent significant level.

However, in the short run the coefficient of technological innovation shows that if INDVA rises, the environmental degradation decrease in most of the countries in the Congo basin. This is proven by the magnitude of the coefficient of INDVA, for instance the coefficient of technological innovation in Cameroon and Democratic Republic of Congo are negatively significant at 10% threshold or significant level. This implies that any progress in technological innovation will lead to a reduction in environmental degradation. Gabon and the Republic of Congo equally show a negatively and significant coefficient of INDVA at 1% and 5% significant level respectively, this equally shows a negative relationship between technological innovation and environmental degradation as any increase in technological innovation will reduce CO_2 emission.

However, the coefficient of Trade Openness (TROPEN) in the Democratic Republic of Congo and the Republic of Congo is positively significant at 1% level, implying that there is a direct relationship between TROPEN and CO_2. This is to say international trade affects environmental degradation positively or increases CO_2 emissions. This is in conformity with the pollution heavens hypothesis which state that with increased competition, polluting industries in developed countries would tend to move to developing countries due to strict regulations and the rising cost of pollution abatement in developed countries. This hypothesis supports theargument that the increases in CO_2 emissions in developing countries are partly due to the shifting of polluting activities from the developed to the developing countries (Kearsley and Riddel, 2010). But however, TROPEN in Equatorial Guinea shows a contrary result.

Lastly, our findings also suggest that the effect of FDI on emissions become more pronounced in terms of economic and statistical significance. The estimated elasticity indicates that an increase in FDI would lead to an increase in emissions in Cameroon and Equatorial Guinea. It can therefore be asserted that restrictive policies toward FDI inflows are not required in these two countries because of the detrimental impact on the environment. They should therefore encourage FDI inflows particularly in technology intensive and environmental friendly industries and monitor the possible negative effect of pollution intensive inflows on the environment. However, our findings equally suggest that at 1% significant level, an increase in FDI will instead lead to a reduction in CO_2 emissions in DRC and the Republic of Congo. This can be explained by the fact that FDIs at times usually come with technology that is greener andmore environmentally-friendly. This is in line with a study carried out by (Binyam. A, et al 2020) on the effects of FDI on CO_2 emissions which indicates that FDI significantly reduces environmental emissions.

Looking at the results of the quadratic specification in particular, form Table 5 we realized that the coefficients of GDP and the square of GDP for most of the countries are not significant and therefore do not explain the environmental Kuznets curve hypothesis except for Gabon and the Republic of Congo.

The coefficient of GDPC for these two countries shows a positive relationship between GDPC and environmental degradation. The estimated elasticity indicates that an increase in GDP would lead to an increase in emissions for both countries. This result is explained by the fact that GDPC occupies a significant weight in the country’s economy since it is the overall output of goods and services in a given period of time. Taking into consideration this analysis, we can therefore check the validity of the EKC,This result is compatible with the work ofAkin (2014).

The square of GDPC on its part is negatively significant at 1% level for both countries. This means that an increase in GDPC2 by 1 unit for example will lead to a reduction in CO_2 emissions.

The positive sign for GDPC and the negative sign for GDPC2 are supporting the Environmental Kuznets Curve (EKC) hypothesis that environmental pollution initially increases with income and then decreases after income reaches a certain level. The turning point is 9.056 US dollars for Gabon and 6.680 US dollars. Up to this level economic expansion harms the environment. The "turning point" level of GDP where emissions or concentrations are at a maximum is calculated using the following formula **$\tau = [-\alpha_2/(2\alpha_3)]$with $\alpha_{3<0}$ and $\alpha_2+2\alpha_3\tau = 0$.** This result ties with the work ofYaya KEHO (2015) who looks at "An Econometric study of the long run determinants of CO_2 Emissions in Cote d'Ivoire. Kaufmann, Davidsdottir, Garnham and Pauly (1994) equally found support of the EKC using a sample of 13 developed and 10 developing countries from 1974-1989.

4. CONCLUSION AND POLICY RECOMMENDATIONS

This paper examined the issues of demography and technological innovation affecting the environmental degradation in the Congo Basin. The regression results have proven that the demographic transition and technological innovation have negative impacts on environmental degradation. As predicted by the demographic transition model (Werren Thompson 1929) referring to a shift from high birth rates and high death rates with minimal technology, education and economic development to low birth rates and death rates with improved technology, education and economic development, indicates that this region has undergone some level of demographic transition. Again, as technological advancement impacts the standard of living and health care, the higher life expectancies. This might explain why we found demographic transition and technological innovation affecting environmental degradation negatively.

The result equally supports the Environmental Kuznets Curve in two out of the six countries in this region, that is CO_2 increase with income and then decrease after income reaches a certain threshold level. The empirical results provide useful insight to policy formulation and implementation especially as the countries in this region aspires to transform into a fully industrialized economies in the near future. Rapid industrialization requires higher and/or more efficient consumption of energy products. Building a sustainable economic and a cleaner environment should therefore be a shared responsibility between population, the private sector and the government. The different Government of this region should adopt environmental policies that induce industries to adopt new technologies which help mitigate environmental pollution.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

1. FAO. State of the World's Forests 2007. FAO Forestry Report, Forest ResourcesDivision, FAO, Rome. 2007;140.
2. Duterme B. Déforestation: Causes, Acteurs et Enjeux. Alternatives Sud, Paris. Seealso: Le Business de la Déforestation au Secours du Climat?; 2008. Available:http://www.cetri.be/IMG/pdf/La_Libre_051208_climat-deforest_BD.pdf (Accessed 10.03.2009)
3. Grossman GM, Krueger AB. Economic growth and the environment. Quarterly Journal of Economics. 1995;110(2):353-377.
4. Panayotou T. Empirical tests and policy analysis of environmental degradation at different stages of economic development. Working Paper WP238 Technology and Employment Programme, International Labor Office, Geneva; 1993.
5. Dinda S. Environmental Kuznets CurveHypothesis: A survey.EcologicalEconomics. 2004 ;49 :431-455.
6. Nourry M. La Croissance Economique est-elle un Moyen de Lute Contre la Pollution? Revue française d'économie. 2007;21(3): 137-176. November: 401-416.
7. Bartlett AA. Reflection on sustainability, population growth, and the environment– Revisited.Renewable Resources Journal.1997;15.
8. Daly GC, Ehrlich PR. Population, sustainability and earth's carrying capacity.Biosciences.1992;42:761-771.
9. Houghton RA. Biotic changes consistent with the increased seasonal amplitude of atmospheric CO_2concentrations. Journal of

Geographical Research. 1987;92:4223-4230.
10. Detweiler RP, Hall CAS. Tropical Forest and the Global Carbon Cycle; 1988.
11. Dasgupta Partha. The control of resources. Harvard University Press, Cambridge, Massachusetts; 1982.
12. Çalışkan HK. Technological change and economic growth. Procedia - Social and Behavioral Sciences. 2015;195:649-654.
13. Balsalobre-LorenteaD, Shahbaz M, Roubaud D, Farhani S. How economic growth, renewable electricity and natural resources contribute to CO_2emissions? Energy Policy. 2018;113:356-367.
14. Tang CT, Tan EC.Exploring the nexus of electricity consumption, economic growth, energy prices and technology innovation in Malaysia. Applied Energy. 2013;104: 297-305.
15. Fei Q, Rasiah R,Shen LJ. The clean energy-growth nexus with CO_2emissions and technological innovation in Norway and New Zealand. Energy and Environment. 2014;25:1323-1344.
16. Torras M, Boyce J.Income, inequality, and pollution: A reassessment of theenvironmental Kuznets curve. Ecological Economics. 1998;25:147-160.
17. Andreoni J, Levinson A. The simple analytics of the environmental Kuznets curve. Journal of Public Economics. 2001; 80:269-286.
18. Lorente DB, Álvarez-Herránz A. Economic growth and energy regulation in the environmental Kuznets curve. Environmental Science and Pollution Research. 2016;23:16478-16494.
19. Alvarez-Herranz A, Balsalobre-Lorente D, Shahbaz M,Cantos JM.Energy innovation and renewable energy consumption in the correction of air pollution levels. Energy Policy. 2017;105:386-397.
20. Bruvoll A, FæhnT, Strøm B. Quantifying central hypotheses on environmental Kuznets curves for a rich economy: A computable general equilibrium study. Scottish Journal of Political Economy. 2003;50:149-173.
21. Nordhaus W, Boyer J. Warming the world: Economic models of climate change. Cambridge: MIT Press; 2000. Available:http://dx.doi.org/10.2307/4003253
22. Stigilitz JE, Sen A, Fitoussi JP. Report by the commission on the measurement of economic performance and social progress; 2009.
23. World Commission on Environment and Development (WCED). Our common future. Oxford: Oxford University Press; 1987.
24. Daily GC, Ehrlich PR. Population, sustainability and earth’s carrying capacity’.Biosciences.1992;42:761-771.
25. Geroski Paul. Markets for technology: knowledge, innovation, and appropriability. In Handbook of the Economics of Innovation and Technological Change, Ed. Paul Stoneman. Oxford: Blackwell Publishers. 1995;90–131.
26. Boserup Ester. Environment, population and technology in primitive societies. Population and Development Review.1976;2:21-36.
27. Antweiler W, Copeland BR, Taylor MS. Is free trade GOOD for the environment? American Economic Review. 2001;91:877-908.
28. Pesaran MH, Shin Y. An autoregressive distributed Lag modeling approach to cointegration; 1999.

APPENDIX

Appendix 1. Pedroni cointegration test

```
Pedroni test for cointegration
______________________________

Ho: No cointegration                         Number of panels       =      6
Ha: All panels are cointegrated              Avg. number of periods =   27.5

Cointegrating vector: Panel specific
Panel means:          Included               Kernel:            Bartlett
Time trend:           Included               Lags:              3.00  (Newey-West)
AR parameter:         Panel specific         Augmented lags:    1

Cross-sectional means removed
------------------------------------------------------------------------------
                                             Statistic          p-value
------------------------------------------------------------------------------
 Modified Phillips-Perron t                    2.5818           0.0049
 Phillips-Perron t                            -7.3454           0.0000
 Augmented Dickey-Fuller t                    -5.8171           0.0000
------------------------------------------------------------------------------
```


Peer-review history:
The peer review history for this paper can be accessed here:
http://www.sdiarticle4.com/review-history/63086