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Does the environmental Kuznets curve for deforestation exist for Ghana? Evidence from the bootstrap rolling window Granger causality test approach

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Abstract

Purpose – This study investigates the existence of the environmental Kuznets curve (EKC) for deforestation for Ghana over the 1962–2018 the time period.

Design/methodology/approach – The study employs a time-varying approach, the bootstrap rolling window Granger causality test to achieve its set objectives.

Findings – The results from our study reveals an inverted "*N*" shape EKC for deforestation, implying that deforestation will initially decrease with increases in economic growth up to a certain income threshold and increases with further increases in economic growth beyond this income threshold up to a higher income threshold and then decrease with further increases in economic beyond the higher income threshold.

Practical implications – The results from the study project show that over time economic growth can serve as a natural panacea to cure and mitigate the ills of deforestation that have plagued Ghana's forests over the years.

Social implications – The results further highlight the important role of strong institutions in fighting the deforestation menace.

Originality/value – The originality of this study lies in its methodology which allows for feedback from deforestation to the economy. This is in contrast to earlier studies on the EKC for deforestation which allowed causality only from deforestation to the economy.

Keywords Environmental kuznets curve, Deforestation, Bootstrap rolling window Granger causality, Gross domestic product, Ghana

Paper type Research paper

1. Introduction

Globally, deforestation has been recognized not only as a very serious environmental concern but also as a vast and intriguing complex phenomenon which is occurring around the world at a very alarming rate. It is estimated that approximately between forty-six thousand to fifty-eight thousand square miles of forest area is displaced every year by virtue of deforestation. This translates to about 48 football fields of forest disappearing every minute [1]. Forests

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cover approximately 31% of the surface of our planet, and hence its removal will inevitably have dire consequences for the planet [2]. Deforestation, in addition to its local repercussions generally has spillover effects into other neighboring countries. In fact, the problem of deforestation is more of a global nature than a local menace. The repercussions of deforestation not only threaten the environment but also very economic likelihood of forest dependent communities. This can be explained by the undeniable fact that almost on every side of the world people exploit valuable forests for purposes of trade or to help them maintain their source of economic livelihood [3]. On the global level, scientists have expressed grave concerns about the repercussions that deforestation threatens to unleash on the environment and the economy. To fully understand the impacts of deforestation, we need to consider the benefits that society loses when forests disappear. In addition to their very important ecological and ecotourism roles, forests support biodiversity and help mitigate climate change [4]. The consequences of deforestation are geographic and also global. Geographically, it can lead to such consequences as permanent loss of animal species and biodiversity, long term resource depletion and flooding ((Ehrhardt-Martinez *et al.*, 2002; Kallbekken, 2000). Globally, deforestation has been cited as a major culprit for aggravating the problem of global climate change through the release of carbon dioxide emissions which are stored in trees [5].

In Ghana, deforestation is posited to seriously affect the productivity of agriculture, hamper essential functions of the environment and hasten the inevitable deterioration of the forests' original ecosystem. It is estimated that between 1990 and 2005 Ghana lost approximately 26 percent of its original forest cover. Deforestation has been found to seriously affect the economics livelihoods of forest dependent people in Ghana (Boafo, 2013). The menace of deforestation in Ghana is multi-faceted with many complex social and economic dimensions. Stylized factors hypothesized to influence deforestation in Ghana are demographic, microeconomic, macroeconomic and socio-political in nature (Acheampong *et al.*, 2019; Appiah *et al.*, 2009; Gyampoh, 2011; Tuffour, 2014).

Previous studies have suggested that environmental degradation maybe a byproduct of expansions in economic activities. Economic growth is thus traditionally viewed as having effects on environmental quality, predicting economic growth to sometimes generate environmental consequences. This assertion has ignited the interest of researchers in exploring the link between the economy and the environment. To a very large extent, anthropogenic causes of environmental degradation are mostly driven by economic activities. In as much as there can be little denying that the economy and the environment are intrinsically interlinked, the exact nature of this relationship is shrouded in much controversy as studies on this theme have produced mixed results. Researchers have sought to examine the exact channels through which the economy affects the environment, in order to develop economic policies that are environmentally friendly.

The innovating empirical studies of (Grossman and Krueger 1991, 1993; Holtz-Eakin and Selden, 1995; Panayotou, 1993; Shafik and Bandyopadhyay, 1992) provoked a springboard for ground breaking studies into discussions on the shape of the relationship between economic growth and environmental degradation. These works refuted earlier consensus of intellectual discourses positing that a linear relationship. Finding a resemblance of an apparent inverted "U" shape link between environmental degradation and economic growth, Panayotou (1993) came up with the concept of the environmental Kuznets curve (EKC) hypothesis, popularly called the EKC hypothesis. Primarily, the EKC hypothesis asserts, that in early periods of development, emphasis is placed on economic expansion with less attention devoted to environmental cleanliness. This insatiable desire for economic growth inevitably leads to extensive resource extraction which combined with technologies which are very unfriendly to the environment results in the degradation of the environment. The hypothesis formalizes the relationship that exists between economic growth and environmental degradation. Graphically, the EKC hypothesis shows an inverted "U" shape relationship between an indicator of environmental pollution and economic growth. In practical terms, the EKC hypothesis implies that environmental degradation increases as income rise up to a certain income threshold and decreases as incomes increases beyond this specified income threshold (Dinda, 2004). Theoretical underpinnings of the EKC imply a unidirectional causality from economic growth to the environment. Predictions from the EKC theory postulate that in the long run, a panacea to environmental degradation may be economic growth. Researchers over the years have tested a variety of indicators of environmental quality such as carbon dioxide emissions, Sulfur monoxide, deforestation, ecological footprint, haze and light pollution to see if they confirm the EKC hypothesis. Similar to other measures of environmental quality, discovering the existence of an EKC for deforestation has not been very straightforward as various researchers have produced different findings leading to conflicting options, which are divided as to the true nature of the EKC for deforestation. A valid EKC for deforestation hypothesis will imply that deforestation will increase with income up to a specified income threshold and then decline afterward with further increase in income beyond the specified threshold.

The EKC for deforestation hypothesis, just like the EKC for many environmental indicators, has been tested on panel of countries as well as single countries. Cropper and Griffiths (1994) analyzed interactions between population growth and income on the stock of forests. The authors confirmed the EKC hypothesis for selected countries in Africa as well as Latin America but not for Asia with estimated income turning points of $4,760 and $5,420, respectively. Barbier and Burgess (2001) examined the validity of the EKC hypothesis for selected economies in the tropical areas of selected African, Asian and Latin American countries. Contrasting with the findings of Cropper and Griffiths (1994), Barbier and Burgess (2001), validated the EKC hypothesis for only the Asian sample with an income turning point of $6,812. Using data comprising 66 countries primarily from the tropical regions of Africa, Asia and Latin, Bhattarai and Hamming (2002) uncovered very strong evidence of an "*N*" shape EKC for deforestation model for the Latin America and Africa sample. The difference in the findings by the three studies could be attributed to the methodologies applied. Ehrhardt-Martinez *et al.* (2002) after examining data from 74 less developed countries (LDCs) in Asia, Africa and Latin, reached the conclusion that urbanization was more significant in explaining the EKC for deforestation hypothesis than GDP per capita. In furtherance of the result by Ehrhardt-Martinez *et al.* (2002), Marquart-Pyatt (2004) revealed an EKC for deforestation driven by urbanization, confirming that the EKC for deforestation may be driven by urbanization rather than economic growth. The role of institutions in flattening the EKC for deforestation has generated interest among environmental economists in the recent decades. To this end, Culas (2007) assessed the role of institutions in securing property rights and better environmental policies on the EKC relationship for deforestation and found an inverted "U" relationship for deforestation in Latin America but not in Asia and Africa. Moreover, Shandra (2007), finding no support for the EKC hypothesis support of the EKC relationship between deforestation and economic growth asserted that repressive nations create an appropriate and serene business environment for multinational capital, which in turn influences deforestation. Examining the role of institutions in the deforestation process, Murtazashvili *et al.* (2019), finding support of an "*N*" shaped EKC for deforestation and highlighting the crucial role played by institutions in curbing the deforestation menace. Zambrano-Monserrate *et al.* (2018), after testing the EKC for deforestation found an inverted "U" shape EKC for deforestation for all the selected countries in the sample with the exception of Greece, which revealed a one-way direction from GDP per capita to deforestation. Esmaeili and Nasrnia (2014) performed an econometric investigation of deforestation in Iran and confirmed the existence of an inverted "U" shaped EKC for deforestation in Iran, meaning that economic growth could be suffice as a solution to curing the repercussions of deforestation. Further, Waluyo and Terawaki (2016) found an inverted "U" shaped EKC for deforestation in Indonesia, with the income turning point estimated at $990. Using carbon dioxide emissions from deforestation as an index for environmental degradation, Tsiantikoudis *et al.* (2019) found evidence of an inverted "*N*" shaped EKC in the short and long run, contrary to the standard EKC which is inverted "U" shaped. Ahmed and Long (2012) found evidence of an inverted "U" shaped EKC for deforestation for Pakistan.

In the past few years, Ghana's economic indicators have shown great progress, bringing the economy's dream of launching unto a path of sustained economic growth into reasonable reach. Indeed, it can be said that over the past years, the economic growth achieved by Ghana has been very remarkable and is projected to achieve higher levels of economic growth even perform better in the coming years. Between the year 2002 and 2012, Ghana's economy has gone through a transition from a developing economy to a lower middle-income economy, experiencing robust growth rates averaging 7% per annum (World Bank, 2013). However, it cannot be overemphasized that in spite of despite Ghana's impressive growth record, its corresponding record on environmental performance has remained arguable unimpressive. Therefore, there is the need to sit back and assess the environmental repercussions of economic growth with reference particular to deforestation. This study is motivated by the need to model the exact nature of the relationship between economic growth and deforestation and proffer policies to control deforestation that is compatible with economic growth.

Our paper differs from existing studies in that it is the first to investigate the EKC for deforestation in Ghana employing the bootstrap rolling window Granger causality test by Balcilar *et al.* (2010). Previous studies that investigated the EKC for deforestation hypothesis in Ghana assumed that the parameters of the EKC were constant over the time period considered by the study. The rolling window bootstrap causality approach, a time-varying approach allows the parameters of the EKC model to vary overtime; allowing for the determination of the actual effect of economic growth on deforestation, hence the determination of the exact and precise shape of the EKC for deforestation. Further, research in the past has primarily assumed causality running from economic growth to deforestation. The rolling window bootstrap causality approach allows testing for feedback effects from deforestation to the economy. Moreover, there is scarcity of empirical literature on the EKC for deforestation in Ghana. This study will add to the existing stock of the literature. The results from our study show that economic growth's effect on deforestation exhibits an inverted "*N*" shaped EKC relationship, implying that deforestation (*DEF*) initially decrease with increases in *GDP* to a certain income threshold and increases with further expansions in *GDP* beyond this income threshold up to a higher income threshold and then decrease with further increases in *GDP* beyond the higher income threshold. The results show that over time economic growth can serve as a natural panacea to cure and mitigate the ills of deforestation that have plagued Ghana's forests over the years. The remainder of this study is organized in the following manner: the second section discusses literature review and theoretical framework for the study. The methodology of the paper is discussed in section three. The presentation and discussions of the empirical results are done in sections four and five respectively. The paper is concluded in section six.

2. Theoretical relationship between economic growth and deforestation

In investigating the true nature of the relationship between economic growth and deforestation in Ghana, the study adopts the EKC hypothesis developed by Panayotou (1993).

The hypothesis posits that, as the economy grows environmental pollution also rises until it reaches a certain income threshold and then declines as income increases beyond this threshold. The EKC hypothesis for deforestation will then imply that initial levels of economic growth are accompanied by higher deforestation rates until the economy gets to a specified income threshold, beyond which further expansions in economic growth ameliorates deforestation. As posited by Panayotou (1993), the EKC in its very standard form posits an inverted "U" shape relationship between economic growth and environmental degradation. Based on standard EKC framework, the EKC for deforestation can be modeled as:

$$DEF_t = \beta_0 + \beta_1 GDP_t + \beta_2 GDP_t^2 + \delta^{/} X + \varepsilon_t \tag{1}$$

where *DEF* is the rate of deforestation. *GDP* represents the real gross domestic product (GDP) per capita and *X* is a vector of macroeconomic control variables, which are microeconomic in nature. The square of the income variable, i.e. *GDP* is included in Eqn (1) primarily to investigate the presence of non-linearity in the deforestation and economic growth relationship. In order for the validity of the inverted "U" shape relationship between economic growth and deforestation to be upheld, the EKC theory requires that $\beta_1 > 0$ and $\beta_2 < 0$.

3. Methodology of the study

3.1 Full sample bootstrap Granger causality test

This study investigated the nature of the Granger-causal relationship that exists between deforestation and economic growth in Ghana employing a rolling window bootstrap Granger causality test within the bivariate vector auto regression (*VAR*) model developed by (Balcilar *et al.*, 2010). The bootstrap rolling window Granger causality test procedure is chosen over the conventional Granger causality test as the latter most often lack the normal accepted asymptotic distributions which is conventionally attributable to certain inevitable changes in the structure of time series models and to a large extent *VAR* models (Sims *et al.*, 1990; Toda and Phillips 1993, 1994). It was as a result of this development that Toda and Yamamoto (1995), in seeking to find a solution to this inevitable and precarious reoccurring situation which affects conclusions of the standard Granger causality tests, proposed a modified Wald test, which had the added property of being asymptotically distributed. Yet still, Monte Carlo simulation results predicted the modified Wald test to be inconclusive in rectifying the existing problem as it inherently failed in small and even medium samples. In furtherance of a definite solution, Shukur and Mantalos (2000) employed critical values of a residual-based bootstrap method, which are effective even in scenarios where the endogenous variables employed are not co-integrated (Balcilar *et al.*, 2010; Mantalos and Shukur, 1998; Shukur and Mantalos, 2000). As further asserted by Shukur and Mantalos (2000), the residual-based bootstrap method is especially suitable for standard asymptotic tests in sample corrected *LR* tests. Given the very obvious superior characteristics, this study adopts the residual based-bootstrap method based on modified LR test statistics to investigate the Granger causality between annual deforestation and real GDP per capita in Ghana. This study employs data on the rate of deforestation (*DEF*) and real per capita GDP from 1962 to 2018. The starting point of the methodological framework for this study is constructing a VAR process between *DEF* and *GDP*. The bivariate VAR (*p*) process that is generated using the RB-based modified LR causality test is constructed as follows:

$$X_t = \theta_0 + \theta_1 X_{t-1} + \ldots + \theta_p X_{t-p} + \varepsilon_t \quad t = 1, 2, \ \ldots, \ T \tag{2}$$

The optimal lag order of the VAR(*p*) defined by Eqn (2) is chosen by the Schwarz information criterion (SIC). In the VAR (*p*) process in Equation (2) above, *X* is a vector which denotes the study variables, *DEF* and *GDP*, i.e. $X_t = (DEF_t, GDP_t)'$. Employing matrix algebra, we can rewrite Eqn (2) as follows:

$$\begin{bmatrix} DEF_t \\ GDP_t \end{bmatrix} = \begin{bmatrix} \theta_{10} \\ \theta_{20} \end{bmatrix} + \begin{bmatrix} \theta_{11}(L) & \theta_{12}(L) \\ \theta_{21}(L) & \theta_{22}(L) \end{bmatrix} \begin{bmatrix} DEF_t \\ GDP_t \end{bmatrix} + \begin{bmatrix} \varepsilon_{1t} \\ \varepsilon_{2t} \end{bmatrix} \tag{3}$$

where $\varepsilon_t = (\varepsilon_{1t}, \varepsilon_{2t})'$ denotes a zero-mean white noise process, which is also an independent nonsingular covariance matrix denoted by Σ, $\theta_{12,k} = \theta_{ij}(L) = \sum_{k=1}^{p} \theta_{ij,k} L^k$, $i, j = 1, 2$ and L denotes the lag operator, defined as $L^k X_t = X_{t-k}$. Using Eqn (3) we can test the null hypothesis that *DEF* does not Granger cause *GDP* ($\theta_{12,k} = 0$ for $k = 1, 2, \ldots, p$). The same equation allows testing the null hypothesis that *GDP* does not Granger cause *DEF* ($L_c \theta_{21,k} = 0$ for $k = 1, 2, \ldots, p$).

3.2 Parameter stability tests

The basic assumption underlining the bootstrap full sample Granger causality test is the stability of the parameters of the VAR(p) model in Eqn (3), in the short run as well as the long run. Violation of this very critical assumption leads to the outcomes resulting from the bootstrap full sample Granger causality test becoming invalid and unreliable. It is imperative therefore to investigate if the parameters of the variables in the VAR model have remained stable over the time period considered by the study. In order to ensure that bootstrap full sample Granger causality test results are reliable to circumvent this seeming challenge and ensure the reliability of the bootstrap full sample Granger causality test, this study employs the *Sup-F*, *Ave-F* and *Exp-F* tests by Andrews (1993) and Andrews and Ploberger (1994) to test for short run parameter stability. As opposed to the *Sup-F* which is designed to test for sudden structural changes, the *Ave-F* and *Exp-F* examines whether the parameters in the VAR model have gradually evolved over the time trajectory considered by the study. To test the long run parameter stability of the VAR model, the paper employs the L_c test from Nyblom (1989) and Hanson (2002).

3.3 Bootstrap sub-sample rolling window Granger causality test

When there is evidence of short run and long run parameter instability in the VAR(p) as depicted in Eqn (3), the bootstrap sub-sample rolling-window Granger causality test developed by Balcilar *et al.* (2010) is implemented. The test divides the full data sample into separate small sub-samples based on a chosen fixed rolling window size. After this, the sub-samples are gradually scrolled from the start to the end of the entire date period. Following Balcilar *et al.* (2010), the detailed steps for the test are outlined as follows: Assume a study that employs time series data with full length denoted by T. From the full sample length, if a fixed-sized rolling window which includes l observations is determined, then the full time series data of length T can be converted to a sequence of T–l sub-samples, namely; $\tau - l + 1, \tau - l, \ldots, T$, for $\tau = l, l + 1, \ldots, T$. The main advantage of the bootstrap sub-sample rolling-window Granger causality test is that instead of conducting a single causality test for the whole sample, a causality test can be conducted for each sub-sample using the residual based modified Likelihood ratio test. The outcomes of results of the bootstrap sub-sample rolling window Granger causality tests can be derived by summarizing all the observed p-values and likelihood ratio test statistics in a chronological manner. The mean of entire bootstrap estimates of $N_b^{-1} \sum_{k=1}^{p} \hat{\theta}*_{12,k}$ denotes the effect of *DEF* to *GDP* where $N_b^{-1} \sum_{k=1}^{p} \hat{\theta}*_{21,k}$ yields the inverse meaning, which is the effect of *GDP* to *DEF*. N_b represents the number of times of bootstrap reiterations. $\hat{\theta}*_{12,k}$ and $\hat{\theta}*_{21,k}$ are derived estimations form the VAR(p) system in Eqn (3). This study considers a 90% confidence interval level and also the corresponding lower and upper bounds, which are primarily the 5th and 95th quantiles of $\hat{\theta}^*_{12,k}$ and $\hat{\theta}^*_{21,k}$, respectively as adopted by Balcilar *et al.* (2010).

3.4 Data

To empirically test for the existence of the EKC for deforestation for Ghana, we employ annual time series data on the two endogenous variables of interest, being real GDP per capita (in constant $2000) denoted by *GDP* and the annual rate of deforestation *(DEF)*. The data are obtained from the African Development Indicators (ADI) dataset, which is available from the World Bank website dataset for the time period 1962 to 2018. The annual deforestation rate (*DEF*) is calculated by the annual percentage decrease in forest area. This is the definition adopted by (Cropper and Griffiths, 1994; Culas, 2007; Ehrhardt-Martinez *et al.*, 2002) [6]. Natural logarithms of the two variables are derived and used for analysis. This study uses the most recent edition of the World Bank's ADI dataset [7] and thus uses the longest available time period.

4. Empirical results

Preceding the performance of the bootstrap full sample Granger causality test and the rolling window bootstrap Granger causality test there is the need for the determination of the order of integration of the two endogenous variables, being *GDP* and *DEF*. This is necessitated by the condition that both procedures require the stationarity of the two endogenous variables used in the VAR model that use Eqn (3). To this end, DEF and GDP are tested for their order of integration using the Philip–Perron unit toot test by Phillips and Perron (1988) and the augmented Dickey–Fuller unit root test by Dickey and Fuller (1981). In Table 1, we present outcomes of the aforementioned unit root testing procedures.

From Table 1 we observe that the null hypothesis of non stationarity failed to be rejected at 5% level of statistical significance. In Table 1 however, we can observe that same is rejected at a statistical significance level of 5%. The unit root results reveal stationarity of the endogenous variables at first difference. That implies that they are integrated of order 1. Satisfying the pre-requisite condition, the paper then constructs a bivariate VAR model with *GDP* and *DEF* as endogenous variables. Premised on Eqn (3) above, the bootstrap full sample Granger causality test between the two variables is performed, with an optimal lag of 2 chosen by SIC. The results as displayed in Table 2 suggest no Granger causality between real

	ADF test Null: variable has uni root		PP test Null: variable has unit root	
Test variable	Test statistic	Critical value at 5% statistical significance	Test statistic	Critical value at 5% statistical significance
DEF	−1.9594	−3.4921	−1.9175	−3.4921
GDP	−0.0258		−0.2011	
	ADF test Null: variable has unit root		PP test Null:variable has unit root	
variable	Test statistic	Critical value at 5% statistical significance	Test statistic	Critical value at 5% statistical significance
DEF	−7.4731	−1.9469	−7.5266	−1.9469
GDP	−4.7427		−4.7427	

Table 1. Augmented Dickey–Fuller (ADF) and Philip–Perron (PP) unit root tests in levels

per capita GDP and deforestation (DEF). This is inconsistent not consistent with the EKC hypothesis as proposed by Panayotou (1993), which asserted a unidirectional causality from economic growth to environmental degradation. To determine the reliability or otherwise of the bootstrap full sample Granger causality test, we perform a parameter stability.

As posited by Balcilar and Ozdemir (2013), due to that likelihood of *t* structural changes being always present in VAR models, the endogenous variables employed therein may yield unstable parameters over time and hence expose the validity and reliability of the bootstrap full sample Granger causality test results. The stability of the parameters of *GDP* and *DEF* and the whole the bivariate VAR model are examined by employing the *Sup-F, Ave-F and the Exp-F* propounded by Andrews (1993) and Andrews and Ploberger (1994)). Moreover, to test the long run parameter stability of the VAR model, the paper employs the L_c test developed by Nyblom (1989) and Hanson (2002), In Table 3, the results of the parameter stability tests are presented.

At 1% levels of significance, the results from Table 3 reveal significant instability in the parameters of the bootstrap full sample VAR models, i.e. *GDP* and *DEF* and the whole VAR system. The results emerging from the parameter stability tests reveal short run as well as long run parameter instability. This renders the conclusions from the bootstrap full sample Granger causality test unreliable. The implication therefore is that the rolling window sub-sample Granger causality test is more suitable to investigate the time-varying Granger causal relationship between *DEF* and *GDP*. Following the works of Pesaran and Timmermann (2005) and Aye (2015), the study chose a rolling window with a fixed size of 15. From Figure 1, we observe from the estimated bootstrapped *p*-values which tests the null hypothesis that GDP does not Granger cause DEF is rejected at a statistical significance of 10% in the 1983–1987,1995–1996 and 2005 sub-sample periods. In Figure 2, bootstrapped estimates of the sum of the rolling window coefficients of GDP on DEF, show that *GDP* has a negative effective on *DEF* in the 1983–1987 sub-sample periods, a positive effect in the 1995–1996 sub-sample period and a negative effect in the 2005 sub-sample period. In Figure 3, we observe that *DEF* Granger causes *GDP* at the 10% statistical significance in the 2005 sub-sample period. From Figure 4, we observe that *DEF* influences *GDP* positively in the 2005 sub-sample period. The foregoing analysis form Figures 1–4 reveal causality from *GDP* to *DEF* with feedback from *DEF* to *GDP*.

Test	Null: GDP does not Granger cause DEF		Null: DEF does not Granger cause GDP	
	Statistic	Prob. value	Statistic	Prob. value
Bootstrap LR test statistic	5.3648	0.1252	2.8490	0.2380

Note(s): probability values were generated employing 10,000 bootstrap repetitions

Table 2. Bootstrap full sample Granger causality test

Tests	*GDP* LR statistic	*GDP* *p*-value	*DEF* LR statistic	*DEF* *p*-value	VAR system LR statistic	VAR system *p*-value
Sup-F	39.6077***	0.0000	32.2015***	0.0000	52.4133***	0.000
Ave-F	15.7373***	0.0000	14.3697***	0.0000	23.9567***	0.000
Exp-F	15.9350***	0.0000	12.5108***	0.0000	22.3371***	0.000
L_c					4.1092***	0.005

Note(s): probability values were generating by employing 10,000 bootstrap repetitions; *** denotes 1% level of statistical significance

Table 3. Test of parameter stability

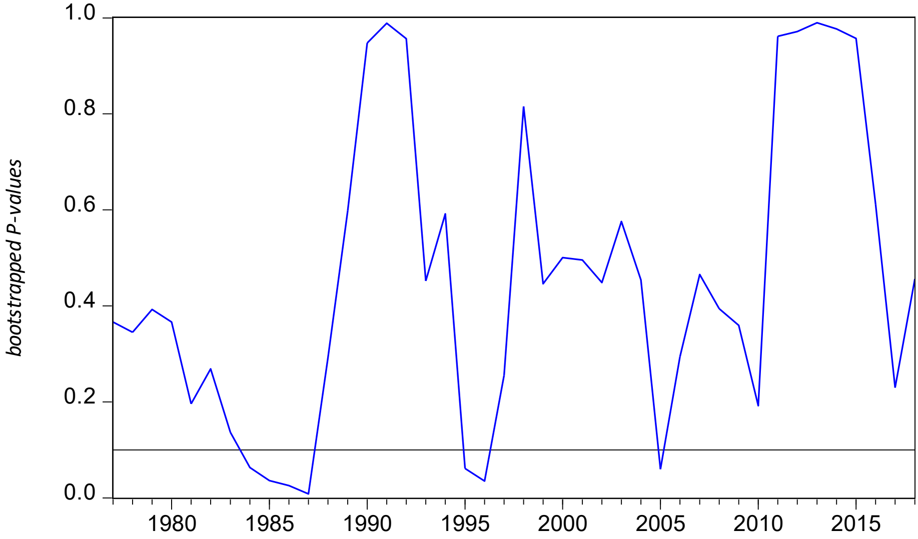

Figure 1.
Bootstrapped probability values for testing the null hypothesis that GDP does not Granger cause DEF

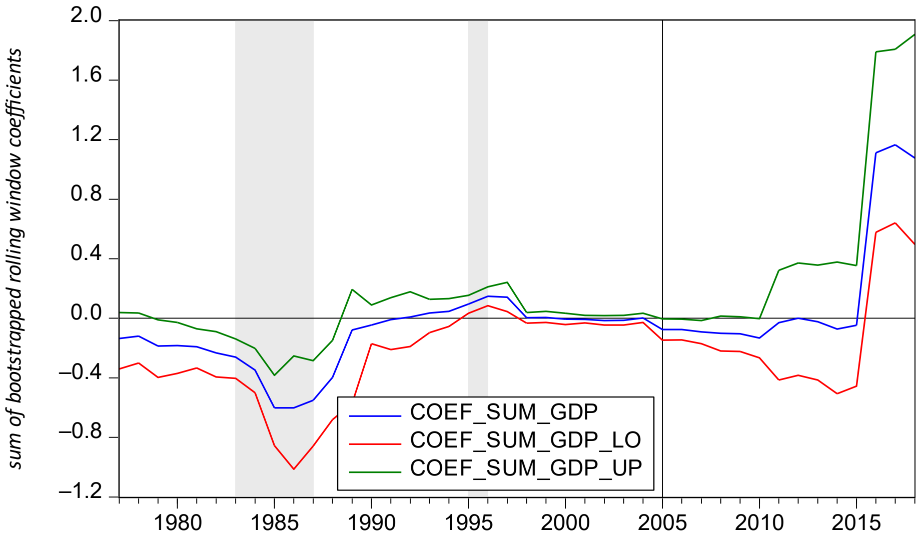

Figure 2.
Bootstrap estimates of the sum of the rolling window coefficients for the impact of GDP on DEF

5. Discussion

In Figures 1 and 2, we observe that the effect of *GDP* on *DEF* is non-linear; a negative effective in the 1983–1987 sub-sample periods, a positive effect in the 1995–1996 sub-sample period and a negative effect in the 2005 sub-sample period. The sub-sample period 1983 to 1987, a period during which economic growth in Ghana improved deforestation, corresponded to the time period during which the country was under strict military rule. During this period the environmental laws were strictly enforced and as such illegal cutting of trees were not allowed.

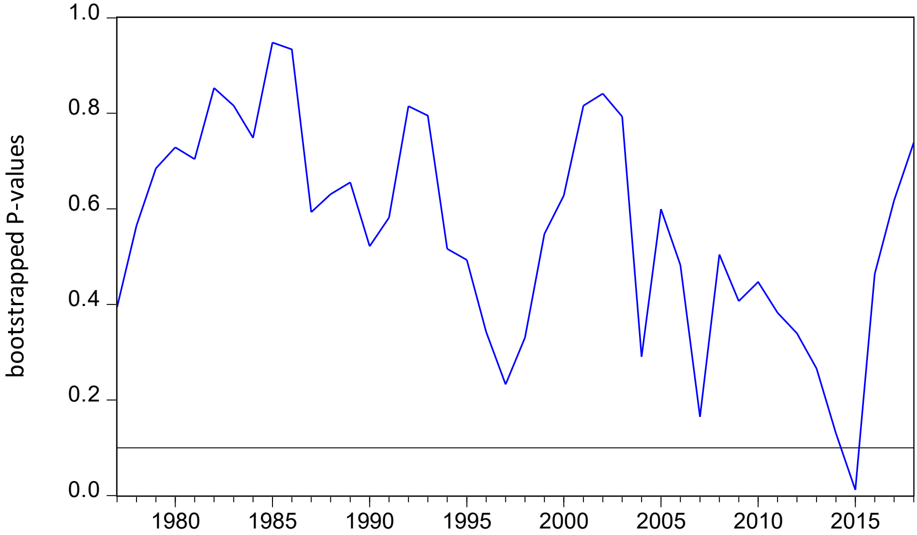

Figure 3. Bootstrapped probability values for testing the null hypothesis that DEF does not Granger cause GDP

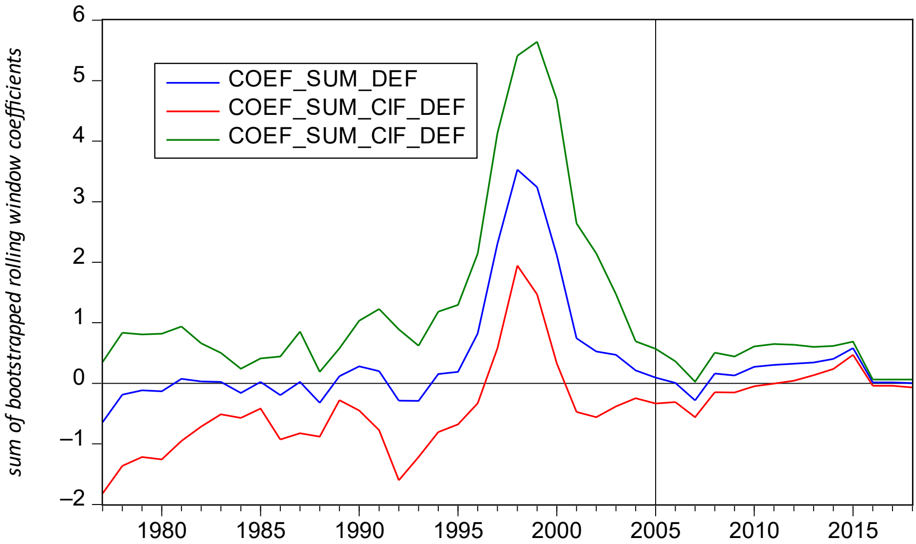

Figure 4. Bootstrap estimates of the sum of the rolling window coefficients for the impact of DEF on GDP

In the 1983–1987 sub-sample period, economic growth was environmental friendly as economic growth was achieved at substantially lower annual rates of deforestation. The military during those periods were an institution and ensured the conservation of Ghana's natural resources. The Trees and Timber (Chain saw Operation) regulation of 1983 which ensure the regulation of felling of trees and logging activities and encouraged forest plantations was in operation. This law ensured that loggers had to obtain licenses and permits before they were able to cut trees. Additionally, loggers were carefully scrutinized before they were given the permit to fell trees. This practice coupled with constant planting of trees led to environmentally friendly growth that Ghana enjoyed within this period. Also, the Forest Protection (Amendment) Act of 1986 which clearly defined punishment for forest offenses, protection of water bodies and species conservation was in full operation during the 1983–1987 period. During this period of time the law governing forestry resources were strictly applied by the military and offenders were summarily convicted and severely punished to serve as a deterrent to other potential law breakers. The Forest Protection (Amendment) Act of 1986 seriously imbued in Ghanaian citizens the spirit of conserving the forestry resources for the present as well as the future generations. In these sub-sample periods, we observe that increases in *GDP* lead to a reduction in the annual rates of deforestation (*DEF*).

Democracy had set in Ghana during the period 1995 to 1996. With the military handing over to a constitutionally elected government, all the rigorous strictness of the military enforcing the law slowly phased out. The laws simply existed on paper but they could not be strictly enforced as the military would have done. These periods in Ghana were characterized by extensive illegal cutting of trees for firewood and surface mining of gold popular called "*Galamsey*". The laws protecting natural forestry resources were not strictly enforced and punishments for flouting the laws were so lenient that the forest rents obtained from exploiting natural resources far exceeded any punishment that could be meted out to offenders. The forest and wildlife policy was enacted in 1994 to ensure among other things the protection of forests and regulation of timber harvesting and rehabilitating and developing forests that experienced some sort of degradation. Addressing the effectiveness of the Forestry and Wildlife policy of 1994, Boon *et al.* (2009) found that the policy failed to address some very important issues in the management of forest resources in Ghana such as the byzantine structure of the land tenure system, weak institutional and governance structure and ineffective involvement of relevant shareholders. Further, it was revealed that although the Forest and Wildlife Policy of 1994 was well intentioned, many of the activities entailed in the policy were unachievable due to its ambiguity and also because the management of the policy was beyond the capacity of the Forestry commission. These events that occurred in the 1995–1996 sub-sample led to a positive effect of *GDP* on *DEF*.

The 2005 sub-sample period corresponded to the period where *GDP* exerted a negative influence on *DEF*. Since the beginning of the early 2000s, the nation has embarked on extensive re-afforestation programs aimed at increasing its forest area. Also, the punishments for exploiting natural forest resources have been made much stricter as opposed to some previous periods where the laws only existed in the books. This sub-sample period has been characterized by the deliberate strengthening of institutions such as the Forestry Commission to protect the forest resources of Ghana and also the deployment of military personnel to designated forest sites to protect them from exploitation by citizens. In this sub-sample period, the offenses for exploiting forestry resources are being made laws are made clear and are strictly enforced. Economic growth's negative effect on deforestation in this period is accounted for by the role of institutions mandated to deal with protecting the forestry resources of Ghana and also the massive afforestation programs that have been undertaken from the early 2000s.

The results from Figures 1 and 2 reveal the effect of *GDP* on *DEF* depicts an inverted "*N*" shape EKC, contrasting the standard EKC which asserts an inverted "U" shape. Deductively, the implication of the inverted "*N*" shaped EKC for deforestation for Ghana is that deforestation (*DEF*) initially decrease with increases in *GDP* to a specified threshold and then increases as *GDP* increases beyond this threshold up to a higher income threshold and then decrease with further expansions in *GDP* beyond the specified higher income threshold. The results show that, over time economic growth can serve as a natural panacea to cure and mitigate the ills of deforestation that have plagued Ghana's forests over the years. The result of our paper revealing an inverted "U" shape EKC for deforestation in Ghana contrast findings from (Ahmed *et al.*, 2015; Barbier and Burgess, 2001; Cropper and Griffiths, 1994; Ehrhardt-Martinez *et al.*, 2002; Esmaeili and Nasrnia, 2014; Zambrano-Monserrate *et al.*, 2018) who found a "U" shaped EKC for deforestation. However, results from our paper confirms the findings of (Bhattarai and Hamming, 2002; Murtazashvili *et al.*, 2019; Tsiantikoudis *et al.*, 2019) who found an "*N*" shape EKC for deforestation. In Figures 3 and 4, we observe that the effect of *DEF* on *GDP* is strictly positive. This positive effect of *DEF* on *GDP* can be attributed to the increase in forest product exports in the year 2005, which led to an increase in foreign exchange and subsequently increasing economic growth.

6. Conclusions and recommendations

This study investigates the nature of the EKC for deforestation for Ghana employing the rolling window bootstrapped sub-sample Granger causality. The tests of the full sample bootstrap Granger causality test show no causality from *GDP* to *DEF* and from *DEF* to *GDP*. The results of the parameter stability tests revealing short and long run parameter instability, the study proceeded to use the rolling window bootstrap Granger causality test, which revealed causality emanating from *GDP* to *DEF*. The study further found feedback from the environment to the economy. From the findings of the study, it emerges that economic growth can serve as a natural panacea to cure and mitigate the ills of deforestation that have plagued Ghana's forests over the years. Ghana is thus encouraged to expand the growth of the economy with the aim of moving to the declining side of the EKC where increased economic growth improves environmental quality. The shape of the EKC for deforestation for Ghana is primarily explained by the weakening and strengthening of the roles of institutions assigned to protect the forestry sector. In the sub-sample periods where economic growth leg to increase in the annual rate of deforestation, it was observed that the law protecting natural forest resources were relaxed and not being enforced. On the other hand, the sub-sample periods where economic growth ameliorated the annual rate of deforestation were characterized by strict enforcement of the law protecting natural forest resources. This paper therefore highlights the importance of the role in institutions in fighting the menace of deforestation in Ghana. The study recommends that by strengthening institutions mandated to protect natural forest resources, Ghana's forest can fully benefit from the gains of expansions in the economy. Economic growth can thus be achieved without sacrificing forest resources. *This study is limited to the extent that the income thresholds for the EKC for deforestation in Ghana were not estimated.*

DECLARATIONS

Ethical Approval - Not Applicable
Consent to participate - Not Applicable
Consent to publish: The authors jointly consent to the publication of our work upon acceptance.
Availability of data and materials: Data on annual rates of deforestation and GDP per capita used in this study sea are openly available at the Havard Dataverse repository https://doi.org/10.7910/DVN/PGG9XA

Competing interests

Author's competing interests: The authors jointly declare no competing interests in this study
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Author's contributions: MKM conceptualized the whole study, performed the data analysis. XZ supervised the whole work. PNG wrote the literature review. AB did a proof read of the whole work. The final work was read and approved by all authors.

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Notes

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2. Adams, Emily. 2012. "Eco-Economy Indicators - Forest Cover| EPI". *Earth-Policy.Org*.http://www.earth-policy.org/indicators/C56
3. http://www1.american.edu/ted/projects/tedcross/x*DEF*or21.htm
4. https://rainforests.mongabay.com/09-consequences-of-deforestation.html
5. *The United Nation's Food and Agriculture Organization (FAO) in a report in October 2006 revealed that contrary to people's perception that global warming was caused by burning oil and gas, in fact between 25 and 30 percent of the greenhouse gases released into the atmosphere each year – 1.6 billion tonnes – was caused by Deforestation.*
6. DEF $= \frac{(F_{t-1} - F_t)}{F_{t-1}}$, where F_t and F_{t-1} are defined as the total forest area in Ghana at time and time $t-1$ respectively
7. The data on Forest are from 2012 to 2018 are based on approximations from the Food and Agricultural Organization (FAO).

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