INTRODUCTION

Ghana, a renowned country in Africa, is gifted with huge range of untapped natural resources and a variety of energy sources. Conversely, Ghana's energy sector suffers hugely as it remains highly underdeveloped and poorly managed and this adversely affects the economic growth of the country. There are a myriad of factors that affects the environment and the economy. According to Esso, energy is the primary source for propelling economic growth, industrialization, and urbanization. As the population of Ghana is on the ascendency rate, there is an upsurge in demand for energy to meet its increasing production and consumption demands. However, there are concerns about the usage of fossil fuel, as it poses huge environmental degradation and pollution issues.
The emphasis of most economies in recent years is to mitigate environmental deterioration to the barest minimum as the countries embrace massive economic development.5-13

As a result, several researchers are paying attention to the interlinkages among energy consumption, economic growth, and environmental pollutants. Most of the studies, however, have been centered on the developed countries14-19 with few studies20-26 focused on the developing countries either at panel level14,18,21,27,28 or at country level.15,16,24,26,29

The aim of this current study is to investigate the responsiveness of the environment to key macroeconomic indicators of a country. The study specifically examines how the environment of the developing economy, Ghana, responds to key changes in international trade, energy consumption, economic growth, and urbanization. The study is centered on Ghana as from the literature only a few studies have addressed emissions with focus on developing Africa countries. Furthermore, the study focuses on Ghana, as a benchmark, to provide sufficient contribution on the dynamic linkages among environmental degradation, energy consumption, international trade, and economic growth from the perspective of developing Africa countries.

Carbon dioxide emission has been used extensively by several recent studies as the indicator of environmental degradation in the European economies15,18,30; North America31; as well as the developing Asia economies21,32-35 and Africa economies2,22,23,36,37 at either panel or at country levels.

The use of individual pollutants as indicator of environmental degradation, however, fails to give a true picture of the entire impact of energy and economic growth on the environment in the energy-economic growth-environmental degradation nexus since such pollutants only represent a miniature proportion of the environmental degradation.38 This study, therefore, utilizes the ecological footprint as an indicator for the environmental degradation; an approach similarly utilized by Al-mulali et al39 and Ozturk et al. 38 This ecological footprint embodies the environmental limits and the extent that humankind exceeds those limits. It is measured as the total sum of cropland, grazing, fishing, forest, CO₂ emissions, and infrastructure footprints. Ecological footprints, as the indicator of environmental pollution, is a better choice as it encapsulates the entire ecosystem that supports humankind consumption and activities.38 It reveals the impact on the environment in terms of air, soil, and water. It therefore gives a clear and a bigger picture of environmental degradation than any individual pollutant.

This study differs from several recent studies for the following three key reasons. Firstly, this study utilizes ecological footprint as the indicator for environmental degradation to give a true representation of the impact of economic growth and energy consumption on the environment as the use of individual pollutants such as CO₂ and sulfur predominantly in the literature might be misleading.

The individual pollutant represents only but a small fraction of the entire environmental deterioration. Secondly, this study incorporates the influence of structural breaks on the energy-economic growth-environmental degradation nexus. Surprisingly, most of the research on Africa24,27,28,36,40,41 ignored the effect of structural breaks in their analysis, though Africa has witnessed huge political, social, and economic reforms. The structural restructurings are mainly caused by political changes, social and economic reforms, shocks (disasters and unforeseen events), and the performance of policies initiated, among others. These occurrences are critical as they result in the sudden shifts in time series variables during a particular time over a given time frame.

Thirdly, this study extends the frontlines of contemporary knowledge by utilizing up-to-date econometric approaches such as the dynamic ordinary least squares (DOLS), the bootstrap causality, and the innovative accounting approach (IAA) as these approaches are more robust and provide better statistical inferences than the conventional approaches such as OLS (ordinary least square) and Granger causality, predominantly used in the literature. This study utilizes the IAA to reveal the direction of causality among the variables, in the future. It is envisaged that this study will provide reliable and robust results for better policy formulation and implementing of guidelines, policies, and reforms.

The prospect of Ghana’s economy, for the past decades, has been very promising a vivid characteristic of most developing economies. There is strong evidence suggesting ever-ongoing massive reforms in Ghana geared toward boosting the human, social, and economic indicators of the wellbeing of the people. This calls for such research on the energy, economic growth, trade, and environmental degradation with focus on the developing economy, Ghana, while incorporating the influence of structural breaks as depicted in Figure 1.

From the global point of view, the findings of this study are critical for the development of policies, guidelines, and environmental protectionism mechanisms at regional, national, and international levels.

The remainder of the paper is organized as follows: Section two outlines recent literature on the topic. Section three provides the econometric framework utilized in this study, while in section four, the empirical results and findings are discussed. Section five contains the conclusion and possible policy recommendation for Ghana.

2 | LITERATURE REVIEW

The subject of mitigation of environmental deterioration is a topical issue of significant interest. The enormity of prior research in the area attests to this. For instance, several
researchers have investigated the key factors that impact on the environment in the quest to mitigate environmental degradation.

Recent studies on the nexus between key macroeconomic indicators and emission levels may be categorized into the following three main classifications.

First, there is a strand of empirical studies that focused on the linkage among economic growth, energy consumption, and carbon emissions while employing the STIRPAT approach. Most of these prior studies investigated the existence of the environmental Kuznet curve while extending simple analytical tests and the multiple regressions. Most of these researchers typically modeled the stages of environmental deterioration by testing the relationship between per capita income and environmental deterioration through cubic or quadratic expression. These researchers revealed varied EKC shapes: N-shape, inverted N-shape, U-shape, and inverted U-shape relationships across various sectors while employing individual indicators such as environmental indicators such as carbon dioxide emissions, sulfur dioxide, methane, and nitrous oxide, among others.

The use of these individual pollutants, however, does not give a true picture of the entire impact of energy and economic growth on the environment since such pollutants only represent a mini proportion of the environmental deterioration. This calls for studies to elucidate comprehensively the impact of key macroeconomic variables on the environment while utilizing a broader measure (indicator) of the environmental degradation.

The second strand of studies extends the environmental Kuznet curve model through the addition of variables such as trade openness, urbanization, and foreign direct investment. Economic growth, however, remains as a key variable in the testing of the existence of EKC model across the globe.

Researchers support the assertion that urbanization activates adverse environmental issues. Wang et al revealed urbanization as one of the major contributors to the adverse environmental issues in most countries. They examined the existence of urbanization-emissions EKC for OECDs countries at panel level while employing a semiparametric panel fixed-effect regression model. This is vehemently supported by most recent studies.

Ozturk et al utilized income from the tourism industry in investigating the environmental Kuznet curve hypothesis. They posit that when income emanating from the tourism industry escalates, invariably the standard of living also increases and this tends to influence public appreciation of the environment and environmental protectionism. They therefore recommend for institution of programs for tourist to enhance the environment.

The third category examines the causality among the aforementioned variables while employing causality test approaches such as the multivariate cointegration and the Granger causality approaches. Five main hypotheses can be deduced from the extant research on the causal link among energy consumption, economic growth, and environmental pollutants: Thus, energy consumption activates economic growth; economic growth activates energy consumption; the feedback activation; the neutral activation; and urbanization activates environmental deterioration.

First is the widely advocated hypothesis—energy consumption activates economic growth hypothesis. This energy...
consumption activates economic growth hypothesis posits that it is energy consumption that leads to economic growth. The energy-led growth hypothesis depicts a one-way causality from energy consumption to growth. Researchers have provided strong support for the energy-led growth hypothesis as their findings revealed a unidirectional Granger causality successively from energy consumption to economic growth. The following researchers, found the existence of Granger causality from energy consumption to economic growth for the following countries: Algeria, Benin, and South Africa while utilizing the modified Toda-Yamamoto Granger causality analysis in his work on the energy consumption and economic growth with focus on African countries.

Another hypothesis is the economic growth activates energy consumption (conservation) hypothesis. This hypothesis asserts that it is the economic advancement of a country that activates energy consumption and not otherwise. Researchers found the existence of Granger causality from economic growth to energy consumption. They recommend energy conservation as they depict that those conservationism mechanisms will reduce waste and waste products and their negative effect on the growth of an economy. Camarero et al. advocate for more stringent regulations on polluting emissions as their study affirms an existence of a relationship between eco-efficiency and economic development. Most of these studies highlight that economic growth has great tendency to effect change in energy consumption. For instance, Charfeddine and Ben Khediri found that economic growth unidirectionally causes economic growth for United Arab Emirates (UAE), while researching into financial development and environmental quality in UAE for the period 1975-2011. They utilized cointegration with structural breaks result in sudden shifts in time series variables during a particular time over a given time frame. Some researchers attribute the inconsistencies and inconclusiveness of the results are due to the use of varying methodologies, differing time periods, omitted variables, sudden structuring occurrences, and contextual differences.

This study parallels recent empirical approach by several authors who similarly utilized such econometric approach in a country-specific time series multivariate framework. This current study therefore extends current knowledge on the relationships among environmental degradation, energy consumption, urbanization, economic growth, and international trade from the perspective of an emerging African country.

This study is crucial for policy formulation and future reforms on trade, energy, and economic growth of developing, emerging, and developed economies.

3 | DATA AND THE ECONOMETRIC APPROACH

This section covers the data and source of data for the analysis. It also presents the econometric framework utilized in the study.

3.1 | Data and data source

This study parallels recent empirical approach by several authors who similarly utilized such econometric approach in a country-specific time series multivariate framework. To avoid the case of omitted variable bias, this study additionally added the following explanatory variables: urbanization and financial development based on the principle of economic development. Recent researchers such as Dogan and Turkekul, Farhani and Ozturk, and Shahbaz et al.
similarly utilized this set of variables while investigating the linkage among environmental pollution and economic growth in their respective studies.

Our study, specifically, examined the dynamic responsiveness of the environment of Ghana to changes in following key economic variables: international trade (imports and exports), energy consumption, urbanization, economic growth, and financial development. For consistency and availability of data for all the utilized variables, this study focused on a study period of 1980-2014. The source of the data for the ecological footprint (environmental degradation) is the Global Footprint Network, while the rest was obtained from World Development Indicators of the World Bank.\(^5\) In this study, the environmental degradation is the dependent variable (measured by ecological footprint, thus sum total of cropland, grazing, fishing, forest, CO\(_2\) emissions, and infrastructure footprints). It depicts the impact on the environment in terms of air, soil, and water. Consequently, the higher the country’s ecological footprint is, the higher the environmental damage. The independent variables are energy consumption (measured by energy consumption per capita in kg of oil equivalent); economic growth (measured by the real gross domestic product per capita); total export (merchandise export per capita); Total import (merchandise import per capita); urbanization (urban population to total population); and financial development (measured as domestic credit to private sector as a share of Real GDP). All the variables are taken at its natural logarithms. This is a common phenomenon in such econometric analyses. The definitions for the various variables utilized in this study are shown in Table 1.

### 3.2 The econometric model

This section explains the econometric approach utilized in this study.

#### 3.2.1 Estimation of the EKC curve

This study investigated the existence of a long-run EKC hypothesis for Ghana under the cubic environmental Kuznet framework as computed in Equation (1) below.

\[
ECO_t = a_0 + \beta_1 Y_t + \beta_2 Y_t^2 + \beta_3 Y_t^3 + \beta_4 ENC_t + \beta_5 X_t + \beta_6 M_t + \beta_7 URB_t + \beta_8 FOD_t + V_t
\]

In investigating the long-run relationship between the ecological deterioration and economic growth of Ghana, this study utilized an up-to-date econometric approach—the DOLS. The DOLS is preferred over the OLS estimators as they overcome the inherent asymptotical bias nature of OLS and over dependence on the nuisance parameters often associated with the presence of serial correlation paramount for small data. DOLS overcomes the issue of endogeneity in the regressors as pointed out by Saikkonen.\(^6\)

The DOLS estimator is captured in Equation (2) as follows:

\[
\hat{\beta} = \frac{1}{n} \sum_{i=1}^{n} \left[ \left( \sum_{t=1}^{T} X_t^i \cdot ECO_t^i \right)^{-1} \left( \sum_{t=1}^{T} X_t^i \cdot ECO_t^i \right) \right]_{1,1}
\]

(2)

where \(X_t^i = [X_t - \bar{X}_t, \Delta X_{t-1} + \ldots + \Delta X_{t+k}]\) denotes the vector of the regressors; and the \(ECO_t^i = ECO_t^i - \bar{ECO}^i\)

### 3.2.2 Unit roots test

Unit roots test is a prerequisite for testing the cointegration relationship among variables as it reveals whether the variables are integrated or not. We, therefore, tested our time series variables initially with the ADF and PP for their stationarity. The ADF and the PP can be used to test whether the data are difference stationary or trend stationary and to determine the number of unit roots at their level.

Our study additionally performed the test for structural breaks in the variables using the Zivot-Andrews unit root test as the developing country, and Ghana has undergone several reforms over the years. According to Esso\(^2\) structural shifts have great tendency of influencing the long-run relationship among the variables. This Zivot unit roots test incorporate and test for the presence of structural breaks unlike the ADF and the PP. It is preferred to the traditional test such as ADF and PP test, because these traditional tests are severely distorted in the presence of structural breaks.\(^2,6^4\)

Our study utilized the Zivot-Andrews under the following three models (Equations 3-5) to test the hypothesis of a structural break in the series at intercept shift, trend shift, and at both intercept and trend shift. To model the structural change, we included dummy variable. The study defined the dummy variable \(D_t(\tau) = 1\) if \(t > \tau\) and 0 otherwise. The parameter \(\tau\) denotes the timing of the break point.

#### Intercept Shift (A)

\[
\Delta ECO_t = \omega_0 + ECO_{t-1} + \gamma t + D_{t, \tau} + \sum_{i=1}^{k} \phi_i \Delta ECO_{t-1} + V_t
\]

(3)

#### Trend Shift (B)

\[
\Delta ECO_t = \omega_0 + ECO_{t-1} + \gamma t + DD_{t, \tau} + \sum_{i=1}^{k} \phi_i \Delta ECO_{t-1} + V_t
\]

(4)
Intercept and Trend Shift (C)

\[
\Delta ECO_t = \omega_0 + ECO_{t-1} + \gamma t + D_{1,t} (\tau) + DD_{1,t} (\tau) \\
+ \sum_{i=1}^{k} \phi_i \Delta ECO_{t-i} + V_t
\]  

(5)

where \( D_{1,t} (\tau) = 1 \) if \( t > \tau \) and 0 otherwise. \( DD_{1,t} (\tau) = t - \tau \) if \( t > \tau \) and 0 if otherwise. The unknown parameter \( \tau \) denotes the timing of the break point and the indicator function taking 1 if the argument of the function is true and 0 otherwise. \( D_{1,t} (\tau) \) is a dummy that captures a shift in the intercept, whereas \( DD_{1,t} (\tau) \) captures a shift in the trend. \( \Delta \) represents the 1st difference of the series.

### 3.3 Test for cointegration relationship

In testing for the presence of a long-run cointegrating relationship among the utilized variables, this study utilized the ARDL bound testing approach by Pesaran et al.\(^\text{65} \) to test cointegration for long-run relationship among environmental degradation, energy consumption, trade, and economic growth in Ghana. The ARDL approach is preferred as it is efficient and consistent even for small sample data. Again, the ARDL bound test does not impose restriction that all variables need to be integrated of the first order. It ignores whether the variables are I (0) or I (1) or mutually or fractionally cointegrated.

Hence, our study utilized the ARDL model to investigate the long-run relationships among the variables. The optimal order lag is selected based on the Akaike information criteria. The optimal estimated ARDL model is (1, 2, 0, 0, 0, 1, 1). The mathematical notations are shown from Equations (6)-(12).

\[
\Delta ECO_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_i \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \\
+ \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \phi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_5 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \\
+ \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t
\]  

(6)

\[
\Delta Y_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_1 \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \\
+ \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \phi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_5 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \\
+ \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t
\]  

(7)

\[
\Delta ENC_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_1 \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \\
+ \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \phi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_5 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \\
+ \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t
\]  

(8)

### Table 1: Variable Definitions

| Variable | Definition | Source |
|----------|------------|--------|
| ECO      | Environmental degradation (measured by the ecological footprint; thus, sum total of cropland, grazing, fishing, forest, CO₂ emissions, and infrastructure footprints) | Global Footprint Networks |
| Y        | Economic growth (real GDP per capita) | World Development Indicators |
| ENC      | Energy consumption (kg of oil equivalent per capita) | World Development Indicators |
| X        | Total export (total merchandise export per capita) | World Development Indicators |
| M        | Total import (total merchandise import per capita) | World Development Indicators |
| URB      | Urbanization (urban population to total population) | World Development Indicators |
| FOD      | Financial development (domestic credit to private sector as a share of Y) | World Development Indicators |
\[ \Delta X_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_1 \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \varphi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_3 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} \]

\[ + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t \]  

(9)

\[ \Delta M_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_1 \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \varphi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_3 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} \]

\[ + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t \]  

(10)

\[ \Delta URB_t = \beta_0 + \beta_2 DUM + \sum_{i=1}^{k} \delta_1 \Delta ECO_{t-i} + \sum_{i=1}^{k} \eta_2 \Delta Y_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_3 \Delta ENC_{t-i} + \sum_{i=1}^{k} \varphi_4 \Delta X_{t-i} + \sum_{i=1}^{k} \gamma_3 \Delta M_{t-i} + \sum_{i=1}^{k} \chi_6 \Delta URB_{t-i} \]

\[ + \sum_{i=1}^{k} \omega_7 \Delta FOD_{t-i} + \lambda_1 ECO_{t-i} + \lambda_2 Y_{t-i} + \lambda_3 ENC_{t-i} \]

\[ + \lambda_4 X_{t-i} + \lambda_5 M_{t-i} + \lambda_6 URB_{t-i} + \lambda_7 FOD_{t-i} + V_t \]  

(11)

As cointegration relationship is confirmed by the ARDL bounds testing cointegration approach, the direction of the causality among environmental degradation, energy consumption, international trade, and economic growth, is tested using the bootstrap Granger causality test. The VECM model is preferred as against VAR model when long-run relationship cointegration is established among the variables. Engle and Granger present that there is causality in at least one direction when there exists a cointegration association among the variables of study.

In our study, the Granger causality test is formulated with the vector error correction model as in Equation (13).

\[
\begin{bmatrix}
ECO_t \\
Y_t \\
ENC_t \\
X_t \\
M_t \\
URB_t \\
FOD_t
\end{bmatrix} = (1-L) \begin{bmatrix}
ECO_t \\
Y_t \\
ENC_t \\
X_t \\
M_t \\
URB_t \\
FOD_t
\end{bmatrix} + \sum_{i=1}^{p} (1-L) \begin{bmatrix}
d_{11}d_{12}d_{13}d_{14}d_{15}d_{16}d_{17} \\
d_{21}d_{22}d_{23}d_{24}d_{25}d_{26}d_{27} \\
d_{31}d_{32}d_{33}d_{34}d_{35}d_{36}d_{37} \\
d_{41}d_{42}d_{43}d_{44}d_{45}d_{46}d_{47} \\
d_{51}d_{52}d_{53}d_{54}d_{55}d_{56}d_{57} \\
d_{61}d_{62}d_{63}d_{64}d_{65}d_{66}d_{67} \\
d_{71}d_{72}d_{73}d_{74}d_{75}d_{76}d_{77}
\end{bmatrix} \begin{bmatrix}
ECO_{t-i} \\
Y_{t-i} \\
ENC_{t-i} \\
X_{t-i} \\
M_{t-i} \\
URB_{t-i} \\
FOD_{t-i}
\end{bmatrix} + \begin{bmatrix}
\lambda_1 \\
\lambda_2 \\
\lambda_3 \\
\lambda_4 \\
\lambda_5 \\
\lambda_6 \\
\lambda_7
\end{bmatrix} \begin{bmatrix}
v_{1t} \\
v_{2t} \\
v_{3t} \\
v_{4t} \\
v_{5t} \\
v_{6t} \\
v_{7t}
\end{bmatrix}
\]

(13)

Our study utilized the bootstrap method developed by Hacker and Hatemi-J method to reassess the evidence of the Granger causality. The critical values of this bootstrap approach are more vigorous and accurate than the asymptotic tests.

The approach in this study for the bootstrap simulations for the Granger causality parallels the approach by recent researchers.

Our study calculated the pseudo-data by applying the estimates under the null hypothesis. Our study specified the Pth lag order for the pseudo innovation term as...
study repeats this step 10,000 times, to obtain 10,000 bootstrapped samples. The 10,000 test statistics \( \hat{\chi}^* \) obtained from the bootstrapped replications enhances the empirical distribution, the accuracy of the critical values, and the new \( P \)-value (bootstrapped \( P \)-value).

The bootstrap causality values, therefore, provide more robust and better statistical inferences.

### 3.5 The innovative accounting approach and the impulse response function

Our study further employed the IAA to predict the direction of the causal relationship among variables in the future. This IAA method overcomes the integral issue of the causality test of being unable to detect the causal relationship among variables beyond the current study period. Consequently, our study forecasts how trade, urbanization, financial development, and economic growth will influence the environment of the developing country, Ghana, for the subsequent ten (10) years.

### 4 EMPIRICAL RESULTS

This section provides the empirical results as well as discusses the findings of the study.

#### 4.1 Summary (descriptive) statistics

The results from the descriptive statistics (Table 2) revealed economic growth as the variable that has the highest mean (6.51), while the lowest mean was recorded by environmental degradation at 1.41. Financial development recorded the highest standard deviation (0.77) depicting that the domestic credit to private sector as a share of GDP in Ghana is very volatile. The government of Ghana is advised to be consistent in the provision of an appreciable amount of domestic credit to the private sector to help boost the economy.

#### 4.2 The long-run estimation of the EKC curve (using DOLS)

This study investigated the existence of EKC curve hypothesis for Ghana in a cubic EKC framework using an up-to-date econometric approach: the DOLS. The results from the long-run estimation of the EKC using the DOLS are shown in Table 3. The results revealed the sign of the coefficient of \( Y \) as negative, the square of \( Y \) as positive, and the cubic \( Y \) as negative. All these coefficients are significant. The cubic framework is valid for inferences with a statistically significant constant, trend, and at trend square. This study confirmed the presence of a long-run inverted N-shaped relationship between economic growth and environmental degradation under the cubic EKC framework hypothesis for Ghana. The study therefore rejects the validity of the traditional EKC hypothesis for the developing country, Ghana. It can therefore be inferred, and initial income (economic growth) is expected to improve the environmental footprint of Ghana. Thus, developing economies, such as Ghana, typically have few productive industries and hence with its low income turning points may still be able to reduce environmental impact. However, beyond at a particular stage of its economic growth leads to environmental deterioration. Thus, expectedly, as the developing economy characterized with a laissez faire environmental grows, the environmental quality will decline with economic growth. However, this deterioration stage seems short-lived as beyond a certain income threshold level (economic growth), it is envisaged the economic growth blossoms into favorable environmental conditions as the country invest more and more of its

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**Table 2: Results from the summary (descriptive) statistics**

| Variable | Mean | Median | Std Dev. | Min  | Max  | Skewness | Kurtosis | Jarque-Bera |
|----------|------|--------|----------|------|------|----------|----------|-------------|
| ECO      | 1.41 | 1.36   | 0.14     | 1.25 | 1.80 | 1.43     | 4.29     | 14.41       |
| Y        | 6.51 | 6.27   | 0.55     | 5.82 | 7.66 | 0.93     | 2.32     | 5.71        |
| ENC      | 5.83 | 5.84   | 0.12     | 5.60 | 6.04 | -0.29    | 2.05     | 1.81        |
| X        | 4.76 | 4.56   | 0.70     | 3.71 | 6.27 | 0.94     | 3.06     | 5.20        |
| M        | 5.09 | 4.94   | 0.74     | 3.90 | 6.54 | 0.54     | 2.27     | 2.45        |
| URB      | 3.71 | 3.73   | 0.17     | 3.44 | 3.98 | -0.14    | 1.70     | 2.56        |
| FOD      | 1.94 | 2.10   | 0.77     | 0.43 | 2.99 | -0.41    | 1.81     | 3.01        |
Results from the long-run estimation of the cubic EKC (DOLS)

| DOLS | Coefficient | t-statistic | P-value |
|------|-------------|-------------|---------|
| Constant | 72.67643 | 2.155319 | .05* |
| $Y$ | −39.85797 | −2.531535 | .03** |
| $Y^2$ | 6.253456 | 2.574926 | .03* |
| $Y^3$ | −0.325978 | −2.621092 | .03* |
| ENC | 0.006819 | 0.083715 | .93 |
| $X$ | −0.05321 | −1.62017 | .13 |
| $M$ | 0.038231 | 1.479549 | .17 |
| URB | 3.965357 | 3.865265 | .00*** |
| FOD | −0.093145 | −2.855854 | .02** |
| DUM | −3.990456 | −2.133111 | .06* |
| $Y \times DUMMY$ | 0.545185 | 2.112519 | .06* |
| @trend | −0.119792 | −5.773813 | .00*** |
| @trend$^2$ | 0.001599 | 6.399179 | .00*** |
| R-squared | 0.95 | SE of regression | .026705 |
| Long-run variance | 0.000216 | Sum of squares of Resid | .007845 |

Note: The dependent variable is ECO.
Abbreviation: DOLS, dynamic ordinary least squares.
*10% significance level.
**5% significance level.
***1% significance level.

income into green activities. The findings supports the prior researchers such as Destek et al., who similarly utilized ecological footprint as the indicator for environment deterioration and found the coefficient of real income on ecological footprint to be negative and the coefficient of the squared real income as positive for the panel mean group estimator while analyzing the EKC for EU countries. In the long run, according to the DOLS (Table 3), this study observed that urbanization has a significant positive impact on environmental degradation. Financial development expectedly leads to a reduction in the environmental deterioration as the government of Ghana provides more financial supports for the development and usage of technologically advanced less emission productive machinery and energies, geared toward a sustainable economic development. Both the dummy variable and its interaction effect on income (Table 3) significantly influenced the dependent variable (ecological footprint). This affirms the notion that structural breaks in various capacities, such as social and economic transformation undertaken in a country, significantly influence the ecological footprint of Ghana and hence need not be ignored.

### 4.3 The unit root test and structural break test

In order to know the order of integration, our study initially tested the unit root properties of the variables utilizing both the ADF and PP unit root tests. The results of the ADF and PP in Table 4 revealed that all the variables as $I(1)$ except environmental degradation (ECO) which is $I(0)$. Thus, they are nonstationary at levels but becomes stationary after the first differencing. Our study complimentarily employed the Andrews-Zivot unit root test, to endogenously determine the timing of structural breaks in the variables for the study period 1980-2014. The following three models were estimated: break in intercept (A); break in trend (B); and break in both the intercept and trend (C). The results of the Andrews-Zivot unit root test shown in Table 5 revealed the presence of structural breaks for the following series: economic growth, energy consumption, export, import, urbanization, and financial development in Models A, B, and C at the 5% level. The dates of the break, however, vary among the variables used for this study at intercept, trend, or both. For instance, for environmental degradation, the breaks correspond to 2008, 1991, and 1990; for economic growth at 2006, 2002, and 2006; for energy consumption at 2006, 2002, and 2006; for export 2008, 2003, and 2001; import 2006, 2003, and 2005; urbanization at 2009, 2000, and 2009; and financial development at 2006, 2001, and 1999 at level, trend, and both level and trend shifts, respectively. The identified breaks coincide with identifiable economic and political shocks. These dates reflect the reforms and structural changes that have occurred in Ghana. For instance, the energy sector of Ghana has suffered setbacks leading to severe power outages threatening the country’s economic growth and transformation in the past decades. These severities deepened in the following years 2000, 2001, 2009, and 2013. Ghana has experienced one of the longest histories of structuring and economic reforms that cut across all sectors. For instance, the energy sector of Ghana was formally instituted with the establishment of the Ministry of Fuel Power in 1978 owing to the energy crises that hit the country during that era. Consequently, the National Energy Board Law was enacted under the PNDCL law 64. In 1984, the Ghana National Petroleum Corporation (GNPC) was established to ensure the energy resources in Ghana are well managed. To further improve, the delivery of energy to most part of the country, especially the northern sector, in 1987 the Northern Electricity Department was established. In the same vein, the trade deterioration in the 2000s, due to the fall in prices of the major trading commodities of Ghana and energy crises accounted for the woeful decline in growth rate, reflected in the breaks of economic growth in the Table 5.
4.4 The cointegration test using ARDL bound testing approach

Similar to the work of Kanjilal and Ghosh,70 Abbasi and Riaz,71 our study used ARDL bound testing approach to cointegration to test for the presence of long-run cointegration. The $F$-statistics confirmed that there is cointegration in the series for the models with the following ensuing dependent variables: environmental degradation; economic growth; export; and import. The ARDL bound test used in this study showed that the $F$-statistics is greater than the upper critical bounds. This study utilized the Narayan 72 critical values. The Narayan 72 critical values are best when the sample study is small as in this case. The ARDL model also confirmed a significant influence of structural breaks on the dependent variables both in the short and long run. To ensure goodness of fit of the model, the diagnostic test and stability test were conducted. The model passed the test of serial correlation and heteroskedasticity. In other words, there was no serial correlation among the variables. The model is not serially correlated, and there is no arch effect with $P$-value of .22 and .11, respectively. Additionally, the plot of both the cumulative sum (CUSUM) and cumulative sum of squares (CUSUM Square) tests, based on the recursive stability test, shown in Figure 2, fell within the critical bounds at 95% confidence level. This signifies the models as robust and stable, hence suitable for econometric analyses and policy recommendation and formulation.

Our study, computed both the short- and long-run ARDL estimates (Table 6). The results as reported in Table 6 revealed that urbanization is a significant contributor to environmental deterioration in both the short and long run. A 1% rise in urban population to total population brings about 33.38% and 115% degradation of the environment in the short run and long run, respectively. As urbanization is on the rise, most afforestation sites are being depleted in Ghana to pave way for infrastructural development matching the economic development pace, hence resulting in the severe degradation of the environment in Ghana in recent times. Our study supports the recent work of Boamah et al73; Al-mulali et al39; Farhani and Ozturk37; Ozturk and Al-Mulali,35 who assert that rise in urbanization leads to adverse environment of countries. To ameliorate the impact of unfavorable impact of urbanization on the environment, this study advocates for improved energy efficiency in the residential and commercial sector as well as complete proper urban use of land. Such proper planning must incorporate environmental protectionism mechanisms, matching the rapid upsurge in urban population to total population characterized in Ghana, in recent times. This study buttresses

| Variable | A | B | C |
|----------|---|---|---|
| ECO      | −4.86 (0.00) | −7.12 (0.00) | −4.76 (0.00) | −2.81 (0.00) | I (0) |
| Y        | −0.98 (0.75) | −0.82 (0.80) | −7.60 (0.00) | −7.63 (0.00) | I (1) |
| ENC      | −1.61 (0.46) | −1.78 (0.38) | −5.23 (0.00) | −5.25 (0.00) | I (1) |
| X        | −0.05 (0.95) | 0.24 (0.97)  | −7.08 (0.00) | −7.10 (0.00) | I (1) |
| M        | −0.57 (0.86) | −0.14 (0.94) | −7.80 (0.00) | −8.55 (0.00) | I (1) |
| URB      | −2.95 (0.15) | −0.63 (0.85) | −4.22 (0.04) | −4.29 (0.03) | I (1) |
| FOD      | −0.87 (0.79) | −0.62 (0.85) | −6.40 (0.00) | −7.84 (0.00) | I (1) |

Abbreviations: ADF, augmented Dickey-Fuller; PP, Phillips-Perron.

| Variable | Intercept (A) | Trend (B) | Intercept and trend (C) |
|----------|---------------|-----------|-------------------------|
| ECO      | −3.83 (0.14)  | 2008      | −4.73 (0.02) 1991       |
| Y        | −6.65 (0.00)  | 2006      | −3.67 (0.00) 2002       |
| ENC      | −4.83 (0.00)  | 2000      | −1.87 (0.00) 2009       |
| X        | −3.10 (0.03)  | 2008      | −3.79 (0.00) 2003       |
| M        | −4.83 (0.01)  | 2006      | −4.89 (0.01) 2003       |
| URB      | −2.63 (0.79)  | 2009      | −6.65 (0.51) 2000       |
| FOD      | −4.10 (0.03)  | 2006      | −4.45 (0.03) 2001       |

TABLE 4 Results of the unit root test

| Variable | At levels | At IST difference |
|----------|-----------|-------------------|
|          | ADF       | PP                | ADF       | PP                |
| ECO      | −4.86 (0.00) | −7.12 (0.00) | −4.76 (0.00) | −2.81 (0.00) |
| Y        | −0.98 (0.75) | −0.82 (0.80) | −7.60 (0.00) | −7.63 (0.00) |
| ENC      | −1.61 (0.46) | −1.78 (0.38) | −5.23 (0.00) | −5.25 (0.00) |
| X        | −0.05 (0.95) | 0.24 (0.97) | −7.08 (0.00) | −7.10 (0.00) |
| M        | −0.57 (0.86) | −0.14 (0.94) | −7.80 (0.00) | −8.55 (0.00) |
| URB      | −2.95 (0.15) | −0.63 (0.85) | −4.22 (0.04) | −4.29 (0.03) |
| FOD      | −0.87 (0.79) | −0.62 (0.85) | −6.40 (0.00) | −7.84 (0.00) |

TABLE 5 Results of the Zivot and Andrews structural breaks unit root test
the call by Wang et al. for improved energy efficiency in the residential and commercial sector and a complete proper urban use of land.

The ARDL long-run estimates (Table 6) revealed that in the long run income ($Y$) will significantly lead to a favorable effect in the environment of Ghana. It is envisaged that with the current pace of economic reforms being carried in Ghana, in the long run the GDP (economic growth) will help mitigate its environmental degradation (Table 6). This is plausible, as the economy develop, Ghana would have more income to be in the position to invest in less carbon dioxide emission energies. This study advocates for more economic reforms to boost the economy of Ghana. To sustain the environment into the future and not jeopardize, it is expected that the country continually invest its improving income in green activities.

Financial development significantly and favorably influences the environment in the long run. Our study supports the work of Al-mulali et al., Jalil and Feridun, Shahbaz et al., who assert that financial development mitigates environmental deterioration. Our study portrays that the financial sector of the developing country, Ghana, as a key tool for mitigating the environmental impacts as it help stimulate technological advancement, research, and developments geared toward sustainable economic development.

From the Table 6, in the short run, export significantly leads to a decline in ecological footprints by 4.4%. Thus, it lowers the impact of the environment in Ghana in the short run. This is plausible as most of the produce exported by Ghana is in their raw states, having undergone little or no further processing. The extent and scope for Ghana's current export is dominantly based on primary raw agricultural produce with several options for more corroborated exports in finished goods and services yet unexplored or under explored. These products have barely undergone further processing and as such with minimal negative impact on the environment if any.

Our study therefore recommends studies to disaggregate trade into their respective components: imports and exports, in order to clarify their respective influence on the environment. Our study failed to support recent researchers such as Atici, Dogan and Turkekul; Omri who aggregated trade as the ratio of exports plus imports to GDP in their respective studies on the economic growth-trade-environmental nexus. Atici in their study on the EKC and implications for sustainable development in the Central and Eastern Europe for the study period, 1980-2002, found trade (computed as ratio of goods traded to GDP) to be statistically insignificant.

![FIGURE 2](image-url)
Omri,75 similarly, also found trade (computed as ratio of goods traded to GDP) to be insignificant in their study on the CO2 emissions, energy consumption, and economic growth nexus of MENA (Middle East and North Africa) countries while utilizing the simultaneous equations. In investigating the EKC hypothesis while utilizing ecological footprint as the indicator of environmental degradation, Al-mulali et al39 also found trade (TR) to have insignificant effect on the environment of low-income countries and lower middle-income countries. Contrary, Ulucak and Bilgili76 in re-investigating the EKC model by ecological footprint measurement for high-, middle-, and low-income countries found an increase in trade to increase ecological footprint, hence more degradation of the environment that supports the ecosystem.

This current study revealed in the short run, exports contribute favorably to the environment in Ghana whereas the impact of import is insignificant. Recent studies by Destek et al found an increase in trade to favorable influence ecological footprint. To explicate on the influence of trade on the environment, our study recommends studies to disaggregate trade into their respective components: imports and exports. This will help clarify their exact impact on the environment.

4.5 | The causality among the variables

As cointegration relationship is confirmed by the ARDL bound test, this study consequently investigated the direction of the causality among environmental degradation, energy consumption, international trade, urbanization, financial development, and economic growth of Ghana using the recent bootstrap Granger causality approach. This was to reassess the evidence of the conventional Granger causality. The bootstrapped Granger causality test (shown in Table 7) confirmed a unidirectional causality running from energy consumption to export and urbanization to export. This endorses that a rise in the energy consumptions in Ghana translates into an upshot in its exports of goods and services. Similarly, the rise in urbanization (URB) accounts for the rise in exports of Ghana. Our study, thus, strongly affirms the assertion of Esso2 that energy as a key source for propelling economic growth, industrialization, and urbanization. Moreover, the bootstrapped approach confirmed the long-run conventional Granger causality established for the following: from environmental degradation, economic growth, export, import, urbanization, and financial development to energy consumption; from environmental degradation, economic growth, energy consumption, import, urbanization, and financial development to export; and from environmental degradation, economic growth, export, import and financial development to urbanization. In the long run, the bootstrapped revealed a significant speed of adjustment toward long-run equilibrium of 585%, 46%, and 165%, in energy consumption, export, and urbanization, respectively.

This study therefore recommends the use of bootstrap Granger causality over the VECM Granger causality for statistical inferences especially for emerging economies like Ghana which are prone to structural breaks as vivid from the Andrews structural break test. Additionally, the bootstrap approach developed by Hacker and Hatemi-J67 provides critical values that are more robust and accurate than the asymptotic tests.67,68

4.6 | The innovative accounting approach and the impulse response function

Our study utilized the IAA (ie, the variance decomposition analyses) to overcome the inherent problem of the causality test of being unable to detect the causal relationship among variables beyond the current study period. Our study forecast how the environment of Ghana will react toward changes in economic growth, energy consumption, export, import, urbanization, and financial development of Ghana for the next ten (10) years.

The results of the decomposition analyses, reported in Table 8, indicate that 91% of environmental degradation is contributed by its own standard innovation shock. The environment deteriorates by 1.21%, 4.29%, 0.73%, 1.75%, 0.13%, and 0.42% when a one standard deviation change is imputed in economic growth, energy consumption, export, import, urbanization, and financial development, respectively. For the case of the developing economy, Ghana, though energy consumption happens to be a key variable that propels economy growth, it results in adverse environmental effects as most of her industries use fossil fuels.

The economic growth of Ghana contributes to the environmental deterioration by 1.21% when one innovative shock is imputed in economic growth. A 1% increase in economic growth leads to a rise in environmental degradation up to 3.09% (Period 1-3). However, beyond the peak (period 3), it is envisaged that advancement in economic growth will lead to a decline in the environmental degradation. The IAA revealed that in the future, a 1% innovative shot in economic growth will lead to a decline in environmental degradation by 2.25%-1.21% (Period 4-10). Thus, as the pace of economy growth in Ghana keep on being on ascendency into the future, it will reach a stage, where advancement in the economy would rather lead to improvement in the environment. Our study advocates that Ghana embark on massive economic and structural transformation to boost its economy. As the economy develops, Ghana would have more income to exploit more efficient energies in the quest to mitigate the environmental pollution.
CONCLUSION AND RECOMMENDATION

Our study focused on the dynamic responsiveness of the environment of Ghana to changes in following key economic variables: economic growth \((Y)\), energy consumption \((ENC)\), international trade: imports \((M)\) and exports \((X)\), urbanization \((URB)\), and financial development \((FOD)\) for the period 1980-2014. This study utilized ecological footprint as the indicator for environmental degradation. The ecological footprints (measured as the total sum of cropland, grazing, fishing, forest, CO\(_2\) emissions, and infrastructure footprints) are a better choice as the indicator of environmental degradation than any individual pollutants such as CO\(_2\) and sulfur. The ecological footprint encompasses the entire ecosystem that supports mankind consumption and activities, hence give a true representation of the impact on the environment. This is to aid proper monitoring and consequential implementation of policies and reforms to help sustain the environment into the future.

The central conclusion from this study is that there is an inverted N-shaped environmental degradation-economic growth relationship for Ghana. The DOLS established the existence of an inverted N-shaped environmental degradation-economic growth relationship for Ghana under the cubic EKC framework. The results revealed the sign of \(Y\) as negative, the square of \(Y\) as positive and the cubic \(Y\) as negative. All the coefficients are significant. It can therefore be inferred, the initial economic growth of Ghana is expected to improve its environmental footprint. However, at a certain stage of its economic growth leads to environmental deterioration. This deterioration stage seems short-lived as beyond a certain income threshold level (economic growth), it is envisaged the economic growth blossoms into favorable environmental conditions as the country invest more and more of its income into green activities.

Another key finding is the evidence of significant structural breaks that influence the dynamic linkage among the environmental degradation, energy consumption, international trade, urbanization, financial development, and economic

### TABLE 7: The Granger causality test

| Model (VECM model) | Short-run causality | Long run |
|-------------------|---------------------|----------|
| \(\Delta ECO_t\) | \(\Delta Y_t\) | \(\Delta ENC_t\) | \(\Delta X_t\) | \(\Delta M_t\) | \(\Delta URB_t\) | \(FOD\) | \(ECT\) |
| \(\chi\) | 4.86 (0.09)* | 0.18 (0.91) | 21.73 (0.00)** | 1.27 (0.53) | 3.24 (0.20) | 1.12 (0.57) | 0.15 [0.92] (0.39) |
| \(\hat{\chi}\) | 2.00 (0.15) | 0.05 (0.95) | 0.85 (0.43) | 0.69 (0.51) | 0.91 (0.41) | 3.83 (0.03)** | 0.29 [1.32] (0.20) |
| \(\Delta Y_t\) | \(\chi\) | 1.53 (0.46) | – | 0.74 (0.69) | 6.91 (0.03)** | 0.00 (0.99) | 2.97 (0.23) | 1.85 (0.40) | –0.20 [2.52] (0.02)** |
| \(\hat{\chi}\) | 0.16 (0.85) | – | 0.68 (0.51) | 0.65 (0.52) | 0.10 (0.90) | 0.59 (0.56) | 0.91 (0.41) | 0.18 [0.60] (0.56) |
| \(\Delta ENC_t\) | \(\chi\) | 0.75 (0.69) | 2.16 (0.34) | – | 36.28 (0.00)** | 5.31 (0.07)* | 20.27 (0.00)** | 1.25 (0.54) | 0.02 [0.24] (0.07)* |
| \(\hat{\chi}\) | 0.29 (0.75) | 2.36 (0.10) | – | 2.78 (0.07)* | 1.79 (0.18) | 0.76 (0.47) | 0.01 (0.99) | 5.85 [2.40] (0.03)** |
| \(\Delta X_t\) | \(\chi\) | 0.94 (0.62) | 0.88 (0.65) | 1.93 (0.38) | – | 1.75 (0.42) | 0.64 (0.73) | 2.24 (0.33) | –0.56 [7.61] |
| \(\hat{\chi}\) | 1.24 (0.30) | 4.21 | 0.10 (0.91) | – | 0.18 (0.83) | 0.22 (0.80) | 0.58 (0.56) | (0.00)** |
| \(\Delta M_t\) | \(\chi\) | 0.64 (0.73) | (0.02)** | 0.98 (0.61) | 3.50 (0.17) | – | 5.44 (0.07)* | 0.16 (0.92) | 0.46 [1.96] (0.07)* |
| \(\hat{\chi}\) | 0.45 (0.64) | 1.47 (0.48) | 0.09 (0.91) | 2.72 (0.07)* | – | 0.21 (0.81) | 0.14 (0.87) | 0.23 [2.18] (0.04)** |
| \(\Delta URB_t\) | \(\chi\) | 0.56 (0.75) | 0.91 (0.41) | 2.48 (0.29) | 31.50 (0.00)** | 3.19 (0.20) | – | 3.94 (0.14) | –0.01 [0.04] (0.97) |
| \(\hat{\chi}\) | 3.16 (0.04)** | 1.21 (0.55) | 0.74 (0.49) | 2.75 (0.07)* | 4.25 (0.02)** | – | 5.02 (0.01)** | –0.03 [4.18] (0.00)** | 1.65 [10.88] (0.00)** |
| \(\Delta FOD_t\) | \(\chi\) | 1.39 (0.50) | 0.87 (0.65) | 0.27 (0.87) | 5.93 (0.05)* | 2.19 (0.33) | 2.65 (0.27) | – | 0.05 [0.62] (0.54) |
| \(\hat{\chi}\) | 3.47 (0.04)** | 1.28 (0.29) | 0.60 (0.55) | 1.09 (0.34) | 1.17 (0.32) | 1.70 (0.19) | – | 0.47 [1.80] (0.09)* |

Note: \(\chi\) shows the conventional Granger causality, and \(\hat{\chi}\) shows the bootstrap Granger causality.

Short-run unidirectional Granger causality: \(ECO \rightarrow Y; ECO \rightarrow X; Y \rightarrow X; ENC \rightarrow X; ENC \rightarrow M; ENC \rightarrow URB; M \rightarrow URB; URB \rightarrow X; FOD \rightarrow X\).

Unidirectional Granger causality: \(\hat{\chi}\) \(ENC \rightarrow X; X \rightarrow Y; M \rightarrow X; URB \rightarrow ECO; URB \rightarrow X\) \(URB \rightarrow M\). Bidirectional: \(ECO \leftrightarrow FOD\).
growth for the case of Ghana. The findings from the Zivot-Andrews structural breaks revealed that the traditional tests (ADF and PP) are severely distorted in the presence of structural breaks. These break dates reflect the reforms and structural changes that have occurred in Ghana. Structural breaks significantly influence the emissions of the developing African country, Ghana.

Our study disaggregated trade into its separate individual variables: import and exports; in the quest to clarify their respective impact on environmental degradation, unlike several studies on the energy-trade-economic growth nexus that mostly aggregate trade as the ratio of exports plus imports to GDP. Our findings revealed that, exports, in the short run contribute favorably to the environment in Ghana, whereas the impact of import is insignificant. This is plausible as most of the produce exported by Ghana are in their raw states, having undergone little or no further processing. The extent and scope for Ghana’s current export is dominantly based on primary raw agricultural produce with several options for more corroborated exports in finished goods and services yet unexplored or underexplored. Our findings, however, is in sharp contrast to most studies on developing Africa countries that aggregated trade and generalized that trade has insignificant impact on the environment, from the perspective of developing African countries. Our study, therefore, strongly recommends future studies to disaggregate trade into their respective components: imports and exports, in order to elucidate their respective influence on the environment.

Additionally, the bootstrap Granger causality affirmed the conventional causality tests for these three variables: energy consumption, export, and urbanization both in the short run and long run. In the short run, our study affirmed a unidirectional causality running from energy consumption to export, and urbanization to export. In the long run, the bootstrapped revealed a significant speed of adjustment toward long-run equilibrium of 58%, 46%, and 165%, in energy consumption, export, and urbanization, respectively. The IAA method revealed further that in the future, a 1% innovative shot in economic growth will lead to a decline in environmental degradation by 2.25%-1.21% (Period 4-10). Thus, as the pace of economy growth in Ghana keep on being on ascendancy into the future, it will reaches a stage, where advancement in the economy would rather leads to improvement in the environment.

This current study pioneer empirical research that seeks to investigate the impact on the environment while using a true representative indicator, thus the ecological footprint. In terms of theory, this paper contributes massively by utilizing robust and recent econometric approaches to test key hypotheses to provide better statistical inferences; crucial for policy formulation and future reforms on trade, energy, and economic growth of developing economies. This study provided in-depth knowledge for better understanding of the relationships among trade, energy consumption, and environmental pollution.

Based on the findings and implications of the study, the following policies are recommended:

First, Ghana should enforce policies geared toward cleaner energy usage such as solar, wind, and biofuel energy to boost its economic growth through enhanced energy-efficient productivity of her industries. Again, energy and environmental reforms should be incorporated in the nation agenda and schedules of the country.

Second, this study additionally recommend for a proper coordination at the local, districts, municipal, metropolitan, and regional level as environmental protectionism enforcement is a shared responsibility and not the burden of the government alone. Ghana therefore needs to enforce more appropriate environmental regulations to support ecological economic development. More public awareness of renewable energy and related research and development of green energy technologies should also be pursued.

Third, considering the rapid economic development with upsurge in urban population to total pollution, this study

### Table 8 Results of the variance decomposition analysis

| Period | SE   | ECO  | Y    | ENC  | X    | M    | UR   | FOD  |
|--------|------|------|------|------|------|------|------|------|
| 1      | 0.0447 | 100.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 | 0.0000 |
| 2      | 0.0598 | 90.1350 | 2.2788 | 2.0917 | 3.7626 | 0.5280 | 0.2196 | 0.9908 |
| 3      | 0.0726 | 90.7000 | 3.0997 | 1.4221 | 2.5959 | 0.7702 | 0.4442 | 0.9680 |
| 4      | 0.0855 | 92.5944 | 2.2459 | 1.2055 | 1.9097 | 1.0187 | 0.3242 | 0.7017 |
| 5      | 0.0989 | 92.7313 | 2.0669 | 1.6979 | 1.4303 | 1.2776 | 0.2696 | 0.5265 |
| 6      | 0.1105 | 92.6010 | 1.8248 | 2.1873 | 1.2415 | 1.3328 | 0.2252 | 0.5874 |
| 7      | 0.1201 | 92.3050 | 1.5741 | 2.8390 | 1.0891 | 1.4331 | 0.1934 | 0.5662 |
| 8      | 0.1306 | 91.6871 | 1.4657 | 3.5114 | 0.9502 | 1.7357 | 0.1651 | 0.4850 |
| 9      | 0.1405 | 91.5484 | 1.3375 | 3.9151 | 0.8828 | 1.7749 | 0.1450 | 0.4509 |
| 10     | 0.1499 | 91.4643 | 1.2120 | 4.2883 | 0.7307 | 1.7546 | 0.1332 | 0.4168 |
advocates for the provision of tailored financial supports and incentives across the diverse sectors to help boost the production and consumption of enhanced energy-efficient products and commodities among the populace of Ghana.

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