Economic Expansion and Environmental Degradation in Ghana: A Sector Decomposition Analysis

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Abstract

Recent research has focused on exploring the relationship between economic expansion and environmental degradation, particularly in developing and emerging economies. This has become necessary given the several attempts by economies to increase productivity while safeguarding the environment to foster sustainable development. This study progresses from previous research to examine the disaggregated impact of economic expansion on the environment. Consequently, the study employs the Autoregressive Distributive Lagged (ARDL) approach to cointegration and annual time series data from 1985 to 2015, from the World Bank database, to examine the disaggregated impact of economic expansion on the environment in Ghana. The study finds that initial stages of agricultural expansion tends to deteriorate the environment, but as agricultural productivity increases beyond a certain point, although the effect on BOD and deforestation may still rise, CO_2 emission reduces. More so, expansion in industry results in a rise in all three indicators of environmental degradation, both in the short and long run while a harmful effect was found between expansion in service output and CO_2 emission at the initial stages of productivity, but not in the long-run. The impact on BOD and deforestation is harmful with expansion in service output. The results point to the fact that expansions in agriculture and services will eventually result in the reduction of CO_2 emissions beyond some productivity threshold.

Keywords: Economic Expansion, Environmental Degradation, Environmental Kuznets Curve, Autoregressive Distributive Lagged Models, Ghana

JEL: O44, Q01, Q50, Q53, Q54

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1.0 Introduction

Economic activities inevitably have stern implications on the environment due to considerable material use and the consumption of environmental resources. World Bank (2015) reports that clearing forests to grow crops accounted for about 20 percent of global carbon emissions. Indeed, the quest to expand the Ghanaian economy has culminated in the phenomenal rise in the level of economic activities, coupled with rising urbanization and industrial growth. Accompanying this trend is the potential rise in material, resources and energy consumption, all of which have coincided with the era of heightened global environmental degradation(such as air and marine pollution, desertification, deforestation, loss of biological diversity and climate change). This is also consistent with Aboagye (2017) who argued that economic expansion in Ghana, as it is the case for many developing countries, predictably comes with increase in resource use and production scale, which often results in adverse environmental consequences. This could be particularly plausible because less developed economies generally have limited regulations concerning the protection of the environment unlike developed economies that have often imposed relatively stringent environmental protection laws (Copeland and Taylor, 2003).

The danger of environmental degradation is that, often it tends to become irreversible and imposes damaging costs on the economy resulting in output and human losses, as well as loss of labour productivity from ill-health and loss of crop output. This undesirable observed nexus between economic expansion and the environment has raised major concerns as to whether economic expansion is to be held responsible for increased environmental degradation. For instance, Zhang (2012) revealed that, although pro-growth policies have contributed immensely to China's recent dramatic economic expansion, this rapid economic growth has also created various environmental problems. Dlamini and Joubert (1996) also demonstrated that the increase in industrial development affected the Swazis directly and indirectly to the extent that the atmosphere in most towns were polluted with particulate matter (such as dust, grit, smoke and fumes), sulphur oxides, carbon monoxide, hydrocarbons, nitrogen oxides, lead and a host of other contaminants. Sources of such pollution include motor vehicles, manufacturing industry, power plants, space heating for houses, offices, stores, restaurants, hospitals, schools, hotels, refuse disposal, etc.

In fact, economic literature examining the linkages between economic growth and environmental degradation is enormous. However, a bulk of the prevailing studies on the subject have focused on how the overall economic growth process has affected the environment with little and in some instances no evidence on how the growth of the different sectors of the economy is contributing to establishing this nexus. This is because the effect of economic growth on the environment depends on the type and source(s) of growth. For instance, some economic activities are based on investments and services, which reduce pollution and natural resource use. Indeed, other economic activities contribute to produce the opposite result. For instance, in Ghana economic activities such as agriculture, manufacturing, construction, mining, processing, and transportation deplete the stock of natural resources, but do not deplete by the same quantum (Aboagye, 2017). Generally, economic growth has been an important driver of change with multiple evidence of negative impacts on the global environment and its ecosystems. Therefore, a sectoral version of the ongoing empirical investigation on the linkages between economic growth and environmental degradation is useful to identify which sector is linked with environmental degradation. This would shape policies intended to effectively tackle the undesirable adverse growth-environment nexus for a number of reasons. First, finding or failing to find a relationship between aggregated environmental sustainability and aggregated economic growth, might hide the relationships between specific environmental endowments and disaggregated economic growth. More so, the use of aggregated growth data means that it is not possible to identify the effect of the various sources of growth on the environment (also see Sari *et al.,* 2008). Furthermore, estimating the relationship between aggregated environmental sustainability and aggregated economic growth is of little or no value to policy makers when it comes to isolating the contribution that different components of the environmental endowment mix make to economic growth and even to sectoral growth and their effects on environmental sustainability (Lean and Smyth, 2013). Thus, this empirical analysis is particularly relevant to examine the individual effects of sectoral growth underlying environmental degradation in Ghana.

This study makes important contributions to literature distinctively as it offers useful insights on how stimulating economic growth from a particular sector could cause environmental degradation, an important aspect of the growth-environment nexus, which has not been adequately examined in the literature. Finally, this paper offers useful evidence, which is expected to shape the design and implementation of appropriate policy action that can pragmatically help in mitigating the adverse effects of sectoral growth policies on the environment.

The remainder of this study is organized as follows. A brief review of related literature is presented in section 2 while section 3 discusses the econometric methodology underpinning the empirical estimation. Major findings are discussed in section 4 and section 5 concludes the paper and provides some recommendations for policy.

2.0 Brief Literature Review

Grossman and Krueger (1995) asserted that there exists an inverted U-shape relationship between economic expansion and degradation of the environment. This idea has been captioned in the environmental economics literature as the Environmental Kuznets Curve (EKC) hypothesis. The underpinning idea of the EKC is that, as an economy experiences growth in output over time, the benefits emanating from increasing income levels are so much needed in the early stages of the output expansion process to the extent that, the need to maintain the general quality of the environment is given little regard. Increasing output levels therefore result in declining environmental quality. However, as income rises beyond a certain threshold owing to expanding output, additional rise in income (output) stirs up people's demand for improved environmental quality; given that cleaner environment becomes a normal good. At this point, rising income resulting from increasing real GDP brings about higher environmental quality.

Several empirical studies have been undertaken to examine the economic growth and environment nexus using aggregate data on output and the environment mostly in the context of developed countries (Aboagye et al., 2016). These include Antweiler et al. (2001) which reported that a rise in GDP tends to increase SO2 emissions, whereas SO2 emissions decline as per capita output increases. Ramcke and Abdulai (2009) also analysed the connection between growth and degradation of the environment. The authors employed a panel data from selected developing and developed countries from 1980 to 2003. Their analysis revealed that most pollutants tend to increase at the initial level of economic growth but eventually fall as an economy grows beyond a certain threshold, though with some uncertainties. In an empirical analysis of the EKC hypothesis in the US, Grossman and Krueger (1993) discovered an inverted U-shaped relationship between per capita income and SO2 concentrations.

In Ghana, Twerefou et al. (2016)used the ARDL technique and yearly data for the period 1970-2010 to test the validity of the Environmental Kuznets Curve (EKC) hypothesis for atmospheric concentration of CO2. The authors reported that there is a U-shaped nexus between output per capita and CO2emissions, contrary to the notion of an inverted U-shaped nexus suggested by the EKC hypothesis. Regarding the drivers of CO2 emission levels in Ghana, the study brought to light that, the consumption of energy and trade openness positively influence emissions of CO2 in the long-run.

As observed in the preceding studies, Kwakwa et al (2015) noted that the empirical studies of the economic growth-environment nexus have mostly employed aggregate data on economic growth and environmental degradation with little focus on the impact of sectoral output growth on the environment; particularly the special instance of growth in agriculture and industry. The authors assert that evidence of the effect of output expansion in different sectors (agricultural, industry and services) could provide relevant information to develop public policy instruments geared towards sustainable development in which environmental quality is safeguarded in the course of output expansion in various sectors of the economy. From the foregoing, the authors made use of annual time series data from the World Bank(World Development Indicators) for the period 1971-2008 and the Johansen cointegration approach to analyse the impact of agricultural growth as well as industrial growth on the environment in Ghana. The authors, through their analysis, confirmed the existence of a long run EKC hypothesis in the agricultural and industrial sectors of Ghana. Likewise, Tang and Shahbaz (2013) using the ARDL cointegration approach and annual data from 1972 to 2010 in Pakistan emphasized on the dire need to analyse the growth-environment relationship at the disaggregate level. However, the results of their cointegration and Granger causality test among energy consumption, CO2 emissions and economic growth with disaggregate data revealed mixed and inconclusive relationship.

In a related study, Nain et al. (2017) utilized annual time series data from 1971 to 2011 to examine both the short-run and long run causal relationships among real GDP, energy consumption, and CO2 emissions at the aggregate and disaggregate (sectoral) levels. The analysis with ARDL revealed that a long-run relationship exists among the variables at both aggregate and disaggregate levels. The Toda–Yamamoto causality tests showed that the long run and short-run causal relationship between the variables is not uniform across the different sectors analyzed. The analysis further pointed out that there is a short-run causality running from electricity use to output growth, and electricity use to CO2 emissions. More so, Uttara et al. (2012) report that the expansion in industrial activities, urbanization and the rising number of vehicles in the urban centers in particular have adverse impacts on the quality of the environment. Uttara et al. (2012) admitted that, this was caused via avenues such as the creation of slum areas, land insecurity, pollution of rivers flowing through cities, inappropriate disposal of waste, and noise and air pollution among others. Mani *et al*. (2006) reported that increasing trade openness in Vietnam has resulted in rising manufacturing and export-oriented activities in 24 water and toxic pollution-intensive sectors relative to the period before the country embraced free trade policies. The authors emphasized on the fact that free trade has changed the output mix of Vietnamese GDP away from traditional sectors and inclined towards pollution-intensive manufacturing products, notably textiles and leather. Wang et al. (2013) reported that factors such as urbanization, real GDP per capita, high population growth rate, industrialization level as well as growth in the service sector caused an increase in CO2 emissions in China. In particular, the authors discovered a positive nexus between the formation and development of heavy industrialized areas, CO2 and SO2 emissions in China.

Aboagye et al. (2016) used a System Generalized Method of Moments and a panel dataset from 1985 to 2010 on 36 countries in Sub-Saharan Africa to estimate the environmental impact of output growth with particular emphasis on disaggregated growth. Seeking to explore the dynamic behaviour of the environment, the authors reported that the impacts of the industrial and service activities on environmental quality are ambiguous, mixed and inconclusive as the environmental effects of growth in the two sectors is highly influenced by how one measures environmental quality. However, growth in agricultural was found to have an enhancing effect on various measures of environmental quality used in the study.

The brief review presented above attests to the fact that there is relatively little empirical analysis of the disaggregated effects of output expansion on the environment in Ghana. Thus, the present study seeks to contribute to the empirical debate in Ghana, which has experienced significant economic expansion in the last three decades but with uneven growth in its three main sectors.

3.0 Methodology and Data

3.1 Theoretical framework

Several studies, including Panayotou, (2003) and Grossman and Krueger (1995), have provided evidence to support the assertion that the two fundamental driving forces of an EKC-pattern are structural changes and technical progress (also see Aboagye, 2017; Aboagye and Kwakwa, 2016; Shafic and Bandyopadhyay, 1992; De Bruyn et al., 1998; Dinda et al., 2000; Hettige et al., 2000). Structural changes entail the transition of the production process from the pollution-intensive industry to the information-based service sector, which is considered as less-polluting (Aboagye and Alagidede, 2016; Panayotou, 2003), or/and any other qualitative reformation of the economic structure. Technical progress includes any improvement in the production techniques, which result in less use of inputs and/or the adoption of less polluting technologies in the production process of goods. Panayotou(2003) and Grossman and Krueger (1995) among other researchers have found that early stages of development are associated with pollution resulting from increasing production and extraction of natural resources. This is called the scale effect of production on environment which results in the upward trend of an EKC. However, when production shifts from primary production to industrial production, economic expansion gives rise to the establishment of information-based industry and services (composition effect) as well as improving production techniques or adopting cleaner technology (technique effect). Both composition and technique effects can overcome the scale effect and generate the downward trend of an EKC curve (Aboagye and Alagidede, 2016; Panayotou, 2003; Grossman and Krueger, 1995; Dinda, 2004).

Kaika and Zervas (2013) have further demonstrated that the composition effect is associated with shifts in production patterns from the more material and energy-intensive manufacturing sector towards the (assumingly) more environmentally-friendly services sector. Pollution is initially generated as the composition of production shifts from light industry (agriculture or textile) to heavy industry (minerals, chemical, machinery etc.) but, subsequently, shifts towards information-based industries and services which are less polluting (also see Panayotou, 2003). The technique effect reflects improvements in technology that allow the use of less inputs per unit of output or the adoption of cleaner technologies that substitute the old and dirtier technologies in the production of goods. The development of cleaner techniques is encouraged by investments in environmental R&D for which, a sufficient level of economic growth is required (Kaika and Zervas, 2013; Neumayer, 1998). Technological progression over time seem to be the major cause of improved environmental quality (Shafic and Bandyopadhyay, 1992). As indicated by De Bruyn et al. (1998) the observed reduced emissions over time could probably be due to advances in technological and structural changes and not due to economic growth. If that be the case, the decline in environmental degradation cannot not be attributable to economic growth as held by the proponents of the famous EKC. In fact, (Lindmark, 2002; Kander, 2005; Lantz and Feng, 2006; Tol et al., 2009) have emphasized the significant effect of technology and structural changes on CO2 emissions over time highlighting that the key factor for this outcome is the evolution of energy consumption and its intensity over time and particularly the shifts in energy mix and in conversion efficiency. As a result, the structure of the oil-dependent economies is transformed with the adoption of new techniques that would lower the energy intensity production and/or the reinforcement of the service sector that is based on a lighter productive structure and hence less energy-intensive production. Dinda et al., (2000) also further confirmed that observed changes in pollution levels over time or even across regions can be ascribed to shifts in production techniques and to sectoral-output composition with respect to SPM and SO_2. Furthermore, Hettige et al. (2000) revealed that the share of industry in total output alone follows an EKC-pattern.

Energy consumption also invariably impact on environmental degradation. For instance, Ramcke and Abdulai, (2009) argue that though renewable energy sources are often environmentally friendly, energy emanating from the burning of fossil fuels/wood etc. entails some pollution, especially air pollution. They further revealed that about a third of all energy consumed in developing countries comes from wood, crop residues, straw and dung, which are often burned in poorly designed stoves within ill-ventilated huts. In addition, energy consumption is closely linked to the depletion of natural resources especially forestry. Thus, energy consumption is another crucial catalyst for environmental degradation or pollution though it could be an indirect form of pollution and environmental degradation (also see Kleemann and Abdulai, 2013). The role energy consumption and/or intensity of consumption play in the degradation of the environment or otherwise could be traced from the evidence that most EKC-empirical studies indicate a rather positive relationship among CO_2 emissions, energy and economic growth (Richmond and Kauffmann, 2006; Luzzati and Orsini, 2009). This is often attributed to the fact that though energy consumption is a major catalyst for economic growth (Humphrey and Stanislaw, 1979; Hamilton and Turton, 2002; Ang, 2007, 2008; Marrero, 2010) it could be the primary source of human-related CO_2 emissions. This is especially in cases where energy is based (mostly) on fossil fuels, in which case any attempt to reduce energy consumption with the aim of reducing CO_2 emissions can have negative effects on economic growth (Chontanawat et al., 2008).

Given the principal focus of the study, and the foregoing discussion, a general representation of the environmental degradation model is specified as follows:

$$\ln ED_t \equiv \alpha_0 + \alpha_1 \ln Y_t + \alpha_2 \ln E_t + \alpha_3 \ln U_t + \alpha_4 \ln K_t + \alpha_5 \ln P_t + \alpha_6 \ln F_t + \alpha_7 \ln T_t$$
$$+ \alpha_8 \ln S_t + \alpha_9 \ln A_t + \alpha_{10} \ln(A_t)^2 + \alpha_{11} \ln I_t + \varepsilon_t \text{...}(1)$$

ED = Environmental Degradation	K = Capital growth	A = Agric. sector growth
Y= Income	P = Population growth	S = Service sector growth
E = Energy consumption	F = Foreign Direct Investment	I = Industrial sector growth
U = Urbanization	T = Trade openness	ε = white noise error term

All variables are expressed in their natural logarithms to minimize the adverse effects of outliers and thereby eliminating heteroscedasticity. Hence, the α's are the elasticity parameters of the regressors in the model. ε_t is the random "disturbance" term, which is assumed to be "well-behaved" in the usual sense and serially independent. Equation (1)is estimated for each of the three disaggregated sectors of the Ghanaian economy. Again, for each disaggregated sector, three separate regressions are estimated for the various forms of environmental degradation. These are CO2 emissions (air pollution), Biological oxygen density (water pollution),and Deforestation (land pollution). The squared term of either Agricultural sector growth (A), Service sector growth (S) or Industry sector growth (I) is included in the model (depending on the particular sector for which the EKC is being tested) to test for the existence or otherwise of the hypothesis with respect to CO2 emissions (air pollution), Biological oxygen density (water pollution), and Deforestation (land pollution). Thus, in totality, nine separate regressions are estimated based on equation (1).

As suggested in the literature, in the case of the existence of the EKC (inverted U-shape nexus between output growth and environmental degradation), $\alpha_9$must be positive and α_{10}must be negative in our representative model presented in equation (1). The coefficients after taking the right signs to confirm the existence of the EKC must also be statistically significant for the EKC hypothesis to hold. The existence of the EKC hypothesis implies that as growth increases at the initial stages, environmental degradation rises but at a reducing rate up to a point beyond which additional growth results in a declining environmental degradation.

3.2 ARDL Approach to Cointegration

We employed the ARDL cointegration technique to examine the long-term relationship among the variables in the study. The ARDL is preferred to other approaches to cointegration such as Johansson (1998) because it is able to generate efficient and consistent results even with small sample data. Below is the specification of the representative unrestricted error correction model in the ARDL framework:

$$\Delta \ln ED_t = \delta_1 + \gamma_1 \ln ED_{t-1} + \gamma_2 \ln Y_{t-1} + \gamma_3 \ln E_{t-1} + \gamma_4 \ln U_{t-1} + \gamma_5 \ln K_{t-1} + \gamma_6 \ln P_{t-1} + \gamma_7 \ln F_{t-1}$$
$$+ \gamma_8 \ln T_{t-1} + \gamma_9 \ln A_{t-1} + \gamma_{10} \ln(A_{t-1})^2 + \gamma_{11} \ln S_{t-1} + \gamma_{12} \ln I_{t-1} + \sum_{i=1}^{n} \lambda_{1i} \Delta \ln ED_{t-i} + \sum_{i=0}^{n} \lambda_{2i} \Delta \ln Y_{t-i}$$
$$+ \sum_{i=0}^{n} \lambda_{3i} \Delta \ln E_{t-i} + \sum_{i=0}^{n} \lambda_{4i} \Delta \ln U_{t-i} + \sum_{i=0}^{n} \lambda_{5i} \Delta \ln K_{t-i} + \sum_{i=0}^{n} \lambda_{6i} \Delta \ln P_{t-i} + \sum_{i=0}^{n} \lambda_{7i} \Delta \ln F_{t-i} + \sum_{i=0}^{n} \lambda_{8i} \Delta \ln T_{t-i}$$
$$+ \sum_{i=0}^{n} \lambda_{9i} \Delta \ln A_{t-i} + \sum_{i(=0)}^{n} \lambda_{10i} \Delta \ln(A_{t-i})^2 + \sum_{i=0}^{n} \lambda_{11i} \Delta \ln S_{t-i} + \sum_{i=0}^{n} \lambda_{12i} \Delta \ln I_{t-i} + \varepsilon_t \text{.............................}(2)$$

We estimated the unrestricted error correction model shown in equation (2)variously to analyze the long-term nexus between the three indicators of environmental degradation and the set of regressors employed for the study. As previously highlighted, it is worthy to note that separate regressions have been estimated for each of the disaggregated sectors of the economy. Again, for each disaggregated sector, three separate regressions are estimated for the various forms of environmental degradation. Thus, in totality, nine separate regressions are estimated based on equation (2).The OLS estimation technique was employed and the F-test for joint significance was computed. In the test for cointegration among the variables, the null and alternative hypotheses, respectively signifying no cointegration and cointegration, are given as stated below:

H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 \text{.................} = \gamma_{12} = 0$
H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \text{..................} \neq \gamma_{12} \neq 0$

In arriving at a decision on the existence of cointegration or otherwise, we compared the computed value of the F-statistic in the model with values of the critical bounds given by Pesaran et al (2001). If the estimated F-statistic is greater than the upper critical value, the H_0 of no cointegration is rejected which in effect implies the prevalence of a long-term equilibrium relationship among the variables. However, we decline to reject H_0 if the computed F-statistic falls below the lower critical bound; meaning there is no long-run equilibrium nexus among the variables in the study. The test for cointegration is inconclusive if the test statistic falls within the upper and lower critical bounds. When evidence of cointegration is established, we proceed to estimate the long run and short-run parameters of the model. The parameters of the long-run ARDL model of lag orders (m,n,p,q,r,s,t,u,v,w,x,y,) is estimated after evidence of a long-run relationship among the variables have been established. The representation of the long-run model estimated have been stated below:

$$\ln ED_t = \beta_1 + \sum_{i=1}^{m} \gamma_{1i} \ln ED_{t-i} + \sum_{i=0}^{n} \gamma_{2i} \ln Y_{t-i} + \sum_{i=0}^{p} \gamma_{3i} \ln E_{t-1} + \sum_{i=0}^{q} \gamma_{4i} \ln U_{t-i} + \sum_{i=0}^{r} \gamma_{5i} \ln K_{t-i}$$
$$+ \sum_{i=0}^{s} \gamma_{6i} \ln P_{t-i} + \sum_{i=0}^{t} \gamma_{7i} \ln F_{t-i} + \sum_{i=0}^{u} \gamma_{8i} \ln T_{t-i} + \sum_{i=0}^{v} \gamma_{9i} \ln A_{t-i} + \sum_{i=0}^{w} \gamma_{10i} \ln(A_{t-i})^2 + \sum_{i=0}^{x} \gamma_{11i} \ln S_{t-i}$$
$$+ \sum_{i=0}^{y} \gamma_{12i} \ln I_{t-i} + \varepsilon_{1t} \text{...}(3)$$

As seen from equation (3)above, β_1 is the intercept of the regression model and ε_{1t} is the error term. The error term is assumed normally distributed and white noise. As stated previously, the

$\gamma_{'s}$ are the long run coefficients and all other variables are as previously defined. Equation (3) is also estimated thrice for each disaggregated sector with the three variables capturing environmental degradation in the study taking turns as dependent variables, which yields a total of 9 regressions. The explanatory variables in the estimations remain the same except for the squared term, which changes depending on the sector in which the EKC is being tested.

3.3 Error Correction Model

The existence of cointegration implies a valid error correction model (Gujarati, 1995). Hence, the representation of the error correction model stated as equation (4) below was estimated to obtain the short-run parameters as well as the rate of adjustment towards long-run equilibrium given a disturbance in the long-run equilibrium relationship (error correction term).Again, it is worthy to note that separate regressions are estimated for each of the disaggregated sectors of the economy. More so, for each disaggregated sector, three separate regressions are estimated for the various forms of environmental degradation. Thus, in totality, nine separate regressions are estimated based on equation (4). From the error correction representation in equation (4) below, β_2 is the intercept and σ is the parameter of the error correction term, which measures the rate of adjustment to long-run equilibrium when there is a disturbance in the equilibrium relationship. The white noise error term is ε_{2t}.

$$\Delta \ln ED_t = \beta_2 + \sum_{i=1}^{m} \lambda_{1i} \Delta \ln ED_{t-i} + \sum_{i=0}^{n} \lambda_{2i} \Delta \ln Y_{t-i} + \sum_{i=0}^{p} \lambda_{3i} \Delta \ln E_{t-i} + \sum_{i=0}^{q} \lambda_{4i} \Delta \ln U_{t-i} + \sum_{i=0}^{r} \lambda_{5i} \Delta \ln K_{t-i}$$

$$+ \sum_{i=0}^{s} \lambda_{6i} \Delta \ln P_{t-i} + \sum_{i=0}^{t} \lambda_{7i} \Delta \ln F_{t-i} + \sum_{i=0}^{u} \lambda_{8i} \Delta \ln T_{t-i} + \sum_{i=0}^{v} \lambda_{9i} \Delta \ln A_{t-i} + \sum_{i=0}^{w} \lambda_{10i} \Delta \ln (A_{t-i})^2 + \sum_{i=0}^{x} \lambda_{11i} \Delta \ln S_{t-i}$$

$$+ \sum_{i=0}^{y} \lambda_{12i} \Delta \ln I_{t-i} + \sigma ETC_{t-i} + \varepsilon_{2t} \quad \ldots\ldots (4)$$

3.4 Causality Test

The existence of cointegration does not necessarily imply causality (Engel and Granger, 1987). In order to ascertain the short and long run causality among the variables, we employ the Engel-Granger causality test over the Toda–Yamamoto test. Unlike the Toda–Yamamoto, the Engle–Granger detects causality through the Vector Error Correction(VECM) model by saving the residuals corresponding to the deviations from the equilibrium points of the long-run cointegration vectors.

3.5 Data

The study uses annual time series dataset from 1985-2015 sourced from the World Development Indicators (WDI) of the World Bank (see http://data.worldbank.org/data-catalog/world-development-indicators). It is worth-mentioning that in the WDI, there hardly exist sufficient data on the relevant environmental variables (i.e. CO_2emissions, Biological Oxygen Density and Deforestation) under study but has considerably consistent data, at least, for sample period of the study. Further, economic growth has been disaggregated into the three broad sub-sectors – namely: Agricultural, Services and Industry and this is to provide a comprehensive outlook of how output and structural composition impact on the environment in diverse ways.

4.0 Results and Discussion of Findings

4.1 Unit root/Stationarity results

The results of the stationarity test as presented in Table 1, indicate that most of the variables are I(1) except for Natural Resource Rent, Industry (% of GDP) and Agricultural (% of GDP) that were found to be I(0). Non-stationarity implies the absence of mean reversion and the possibility of the OLS estimator producing spurious results, except in instances where the series are cointegrated and the regressors are strictly exogenous. The I(0) and I(1) nature of the variables, and the I(1) of the dependent variables (CO2 emissions, Biological Oxygen density and Deforestation) informed the choice of the ARDL estimation technique.

Table 1: Unit root/Stationarity results

	Augmented Dickey-Fuller				Phillips-Peron				Remarks and Decision
	Levels		First differences		Levels		First differences		
Variables	**t-stats**	**Prob.**	**t-stats**	**Prob.**	**t-stats**	**Prob.**	**t-stats**	**Prob.**	
CO2 emissions	1.088	0.908	4.567	0.000	-7.419	0.059	-6.209	0.000	I(1)
Biological Oxygen Density	-0.856	0.839	-3.400	0.031	1.252	0.875	5.008	0.000	I(1)
Deforestation	-1.406	0.646	-8.772	0.000	-0.983	0.918	7.219	0.000	I(1)
Natural resource rent	3.575	0.004	NA	NA	5.551	0.000	NA	NA	I(0)
Energy consumption	-0.077	0.975	-6.971	0.000	-0.114	-1.037	-6.452	0.000	I(1)
GDP per capita	-1.406	0.646	-8.772	0.000	-1.413	0.693	-8.217	0.000	I(1)
Trade expansion	1.491	0.944	-5.819	0.000	-1.682	0.562	-11.48	0.000	I(1)
Population growth	-1.748	0.477	-6.209	0.000	-0.678	0.944	-7.595	0.000	I(1)
Capital growth	-1.579	0.568	-7.344	0.000	-0.794	0.858	-8.086	0.000	I(1)
Industry (% of GDP)	-1.806	0.646	NA	NA	-3.788	0.003	NA	NA	I(0)
Agriculture (% of GDP)	-7.332	0.000	NA	NA	5.403	0.000	NA	NA	I(0)
Services (% of GDP)	-0.667	0.883	-4.046	0.006	-1.912	0.447	-10.45	0.000	I(1)
	Null hypothesis: Unit root				Null hypothesis: Unit root				
	Alternative hypothesis: No unit root				Alternative hypothesis: No unit root				

ARDL Bounds Test for existence of cointegration relationships

Table 2A: CO2 emissions (Air pollution)

	90%	
F-statistic	**Lower Bound**	**Upper Bound**
4.287808	2.348992	3.855872
W-statistic	**Lower Bound**	**Upper Bound**
25.72467	14.32896	23.13958

Table 2B: Biological Oxygen Density (Water pollution)

	90%	
F-statistic	**Lower Bound**	**Upper Bound**
3.1527964	1.727198031	2.8351968
W-statistic	**Lower Bound**	**Upper Bound**
18.915178	10.53598799	17.014381

Table 2C: Deforestation (Land pollution)

	90%	
F-statistic	**Lower Bound**	**Upper Bound**
5.6798612	1.727198031	3.855872
W-statistic	**Lower Bound**	**Upper Bound**
34.0762848	10.53598799	23.139584

The results of the bounds test as presented in tables 2A, 2B and 2C above show the existence of long-run equilibrium relationship (cointegration) among the variables given that the F-statistic is greater than the Upper bound at 10% significance level in all the three tables. The W-statistic is also greater than the upper bound at 10% in all three tables, confirming the existence of long-run relationship (cointegration) among the variables under consideration.

4.2 Presentation of findings and Discussion of Results

In what follows, the study presents and discusses the major findings that eventually emerged through the estimation of the various empirical models in the study. Aboagye (2018) reported that the establishment of long-run cointegration relationships allows for the estimation of both long-run dynamics and the error correction mechanism (short run analysis). The study first presents and discusses the long run findings. It also presents and discusses evidence for or against the EKC hypothesis. Other related findings are also discussed. The final discussion is centred on the test for the existence of valid causal relationships between the indicators of environmental degradation on the one side and disaggregated economic expansion on the other.

4.2.1 Long run evidence

Agricultural sector and environmental degradation

The results of the relationship between Agricultural sector growth and environmental degradation are presented in Table 3a. The results show a positive and significant relationship between agricultural sector growth rate and environmental degradation (as measured by CO_2 emissions, Biological Oxygen Density and Deforestation). This implies that expansions in agricultural activities increase environmental degradation. As agricultural activities intensify, however, the impact on environmental degradation is inconclusive, as it depends on the measure of environmental degradation. Specifically, intensifying agricultural activities results in a decline in carbon dioxide emissions, while Biological Oxygen Density and Deforestation increase. This implies that CO2 emissions increases at a decreasing rate as agricultural growth intensifies which suggests the existence of the EKC hypothesis for carbon dioxide emissions in Ghana's agricultural sector since agriculture has a positive sign while agricultural intensity (measured as agriculture squared) has a negative sign. This conclusion is consistent with the findings by Kwakwa et al (2015) and Aboagye et al (2016). The negative sign recorded as agricultural activities intensify could be attributed to the fact that as agricultural activities intensify, more plants absorb carbon dioxide for photosynthesis, resulting in a reduction in CO_2 in the environment. The positive sign recorded on Biological Oxygen Density and Deforestation, however, could be the result of increased demand for more land as agricultural activities intensify.

Table 3a: Agricultural sector

	Dependant variables					
	CO_2 emissions		**Biological Oxygen Density**		**Deforestation**	
Variables	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dependant variable	0.0045 **	0.0023	0.0011*	0.0006	0.0013*	0.0007
Energy consumption	0.1921*	0.071	0.1151**	0.0464	0.215*	0.115
Natural Resource rent	0.073*	0.013	0.0919**	0.0576	0.0015**	0.0008
GDP per capita	0.1749*	0.711	0.1607	0.3033	0.0919	0.08464
Trade expansion	0.0818**	0.0112	0.0977	0.2347	0.1673***	0.0182
Population growth	0.0244*	0.001	0.097	0.0583	0.1509**	0.00153
Capital growth	0.0107	0.033	-0.041*	0.0221	0.104	0.979
Agriculture growth	0.302***	0.0039	0.0179**	0.00917	0.1422**	0.0125
Agriculture growth intensity	-0.0441**	0.0531	0.01246	0.01539	0.0105**	0.0055
Industry growth	0.1431***	0.0003	0.1044**	0.01981	0.1442***	0.053
Services growth	0.1112**	0.024	0.051	0.05761	0.0245	0.119
Adjusted R-squared	0.760		0.812		0.721	
F-statistic	0.007		0.000		0.005	

Industry sector and environmental degradation

The results in Table 3b show increased environmental degradation as Ghana industrializes. This is evident by the positive coefficient of the measures of environmental degradation. Intensifying industry sector activities in Ghana degrades the environment. The positive coefficients indicate that CO2 emissions, BOD and deforestation increase at an increasing rate at higher levels of industry growth. This confirms the absence of the EKC hypothesis for CO2 emissions, BOD and deforestation in Ghana's industry sector. This finding is consistent with the findings by Dlamini and Joubert (1996) and Uttara et al. (2012). This finding is, however, contrary to the finding by Kwakwa et.al. (2015), who reported the existence of EKC for Ghana with respect to industry. Positive sign as industry sector activities intensify could be attributed to the fact that firms intensifying industry sector activities means more industrial waste to dispose- off. Industrial production results in the emissions of pollutants such as CO2 into the atmosphere, water bodies or even on land resulting in a worsening of the environment. Again, intensifying industry sector activities means the need for more land hence increased deforestation to provide the land needed for industrialization.

Service sector and environmental degradation

The results show an inconclusive relationship between service sector expansion and environmental degradation. This is because Table 3c reports of a harmful impact on Carbon dioxide emissions and Biological Oxygen diversity with service sector productivity, as indicated by their positive coefficients. This means increased environmental degradation (as measured by carbon dioxide emissions and biological oxygen diversity) with increased service sector productivity. However, the impact of service sector productivity on deforestation is rather enhancing afforestation, with a negative coefficient, implying that environmental degradation (as measured by deforestation) declines with service sector expansion. As service sector activity intensifies, Table 3c reports of a decline in carbon dioxide emissions, while biological oxygen diversity and deforestation increase, implying inconclusive results. As reported by Table 3c, there is the presence of the EKC hypothesis for carbon dioxide emissions in Ghana's services sector as shown by the positive coefficient of carbon dioxide emissions with service sector production but a negative coefficient as service sector activities intensify. Table 3c also reports an inverse EKC hypothesis for Ghana, with a negative coefficient for deforestation with service sector activities but a positive coefficient as service sector activities intensify. This shows that as Ghana's services sector expands beyond a certain threshold, the effect on degradation, as measured by deforestation, worsens.

Table 3b: Industry sector

	Dependant variables					
	CO_2 emissions		**Biological Oxygen Density**		**Deforestation**	
Variables	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dependant variable	0.017***	0.003	0.038***	0.005	0.029***	0.003
Energy consumption	0.180***	0.130	0.0508**	0.009	0.282***	0.056
Natural Resource rent	0.026*	0.013	0.041**	0.012	0.021*	0.123
GDP per capita	-0.140**	0.068	0.032	0.166	0.090	0.0860
Trade expansion	0.145**	0.122	0.300*	0.088	0.290**	0.087
Population growth	0.043*	0.022	0.017	0.0104	0.037**	0.003
Capital growth	0.039	0.0215	-0.168**	0.022	0.135	0.120
Industry growth	0.2281*	0.0107	0.0191*	0.0120	0.1151*	0.0100
Industry growth intensity	0.031**	0.027	0.127**	0.008	0.0381*	0.009
Agriculture growth	0.188***	0.0213	0.034*	0.011	0.124***	0.080
Services growth	0.133**	0.018	0.050	0.091	0.087	0.101
Adjusted R-squared	0.790		0.621		0.785	
F-statistic	0.027		0.006		0.000	

Table 3c: Services sector

Variables	Dependant variables					
	CO_2 emissions		Biological Oxygen Density		Deforestation	
	Coeff.	Std. Err	Coeff.	Std. Err	Coeff.	Std. Err
Lag of dependant variable	0.1041**	0.0531	0.08977	0.0127	0.1973	0.0688
Energy consumption	0.1447***	0.021	0.09375*	0.033322	0.2114***	0.0181
Natural Resource rent	0.0811*	0.024	0.09727*	0.0127	0.134465**	0.0245
GDP per capita	0.1091***	0.0096	-0.0121	0.079	0.1215	0.0444
Trade expansion	0.039*	0.015	0.3173	0.1302	0.11569*	0.0130
Population growth	0.02041***	0.0021	-0.0509	0.0769	0.11445**	0.0444
Capital growth	-0.0582	0.1347	-0.0991*	0.02998	-0.10005	0.101
Industry growth	0.2065*	0.0344	0.0179**	0.009	0.1246***	0.0153
Agriculture growth	0.1081*	0.0024	0.2105**	0.101	0.1377**	0.0498
Services growth	0.1744*	0.0084	0.092	0.071	-0.0705	0.128
Services growth intensity	-0.0257**	0.0067	0.024	0.184	0.067	0.072
Adjusted R-squared	0.680		0.613		0.557	
F-statistic	0.003		0.000		0.027	

The EKC evidence

The relationship between economic expansion and environmental degradation is presented in Table 3. The results indicate an inconclusive relationship between economic expansion and environmental degradation. The results presented in Table 3 indicates an inconclusive finding on the presence or otherwise of the EKC hypothesis for Ghana. The positive coefficient of agriculture and the negative coefficient of agriculture intensity, both in relation to carbon dioxide, indicate the presence of the EKC hypotheses for carbon dioxide in Ghana's agricultural sector for the period under consideration. The positive coefficients for industry and industry intensity (measured by the square of industry) for all measures of environmental degradation indicate the absence of the EKC hypotheses for environmental degradation in Ghana's industrial sector for the period under review. The Table 3c shows the existence of the EKC hypotheses for carbon dioxide in the service sector of Ghana with the positive and negative coefficients of the services growth and service growth intensity respectively.

Causality Results

The results of the existence of the causal relationship between economic expansion and environmental degradation using the Engle and Granger causality test is reported in Table 4. The results depict a unidirectional causality between economic expansion and environmental degradation, except for agricultural and services sectors growth; and Biological Oxygen Density, where no causality was observed.

Table 4: Engel and Granger Causality

Null Hypotheses	F-Statistic	P-values	Remarks
Agriculture growth does not Granger Cause CO2 emissions	7.4477	0.0036	Causality
Agriculture growth does not Granger Cause BOD	0.90768	0.7128	No Causality
Agriculture growth does not Granger Cause Deforestation	7.358	0.0036	Causality
Industrygrowth does not Granger Cause CO2 emissions	6.16052	0.0064	Causality
Industrygrowth does not Granger Cause BOD	7.0076	0.0083	Causality
Industry growth does not Granger Cause Deforestation	8.1118	0.0023	Causality
Servicesgrowth does not Granger Cause CO2 emissions	6.91986	0.0042	Causality
Services growth does not Granger Cause BOD	1.51684	0.2029	No Causality
Services growth does not Granger Cause Deforestation	0.4804	0.0023	Causality

Other findings

The results in Tables 3a, 3b and 3c show positive and significant relationship between Energy Consumption and Environmental Degradation. The implication is that, as energy consumption increase, it significantly degrades the environment i.e. a worsening of the environment with increases in energy consumption. Additionally, the relationship between Trade and environmental degradation as reported in Tables 3a, 3b and 3c show a significantly positive relationship between them. By this results, increases in trade activities by Ghana, has the potential of significantly destroying our environment. Moreover, population growth and environmental degradation are positively and significantly related as depicted by Tables 3a, 3b and 3c. This shows that as population increases, environmental degradation also increases. This is because population increase requires increase demand for land for residential purposes, as well as an increased demand for goods. The results of these are depletion of the forests and increased emission of CO_2, implying a degradation of the environment. Finally, technology, represented by capital growth shows a significant negative relationship with environmental degradation (Biological Oxygen Density) as reported in Tables 3a, 3b and 3c. The implication of this finding is that, capital growth (technological improvement) significantly improves the environment.

5.0 Conclusions and Recommendations for Policy

Studies in recent years have focused on the impact of economic growth on the environment. This has been necessitated by the desire of several economies, especially developing economies, to achieve high and sustained growth. Increasing economic output has significant impact on the environment through carbon dioxide emission (air pollution), effect on Biological Oxygen Density (Water pollution) and Deforestation (land pollution). This study focused on exploring the impact of disaggregated economic expansion on the environment while analysing the possible existence of the EKC hypothesis for the various measures of environmental degradation for Ghana. The results show that as agricultural sector activities intensify, carbon dioxide emissions reduce, implying the existence of the EKC hypothesis for Carbon dioxide in the agricultural sector of Ghana. Industrial sector activities, however, turns to have adverse effects on the environment with expansion in industrial sector activities increasing degradation. The result is the absence of the EKC hypotheses in Ghana’s industrial sector for the period under consideration. This shows that carbon dioxide emissions, Biological Oxygen Density and Deforestation would increase as the industrial sector of

Ghana expands. The study also finds that as service sector activity intensifies, carbon dioxide emissions decline. This shows the presence of the EKC hypothesis for carbon dioxide within the context of service sector productivity. Interestingly, increasing service sector productivity would result in an increase in deforestation, implying the reverse EKC situation exist. Increased energy consumption, trade and population growth are all seen to have significant adverse impacts on the environment, while technological growth is found to improve the environment in the long run. Given the negative impact of industrialisation on the environment in Ghana, it is very important for policy makers to develop and implement policies that are growth stimulating but would have lesser negative impacts on the environment. Since technological advancement positively affects the environment, resources should be invested in research and development to ensure the availability of improved technologies for firms. In this regard, policy makers should develop and implement strict trade policies that ensure that goods coming in and moving out of Ghana are of higher quality and environmentally friendly.

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