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Effect of natural resources extraction on energy consumption and carbon dioxide emission in Ghana

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Abstract

Purpose – Even though many studies have attempted to understand the drivers of carbon dioxide emission and energy consumption to help tackle environmental issues, not much has been done to estimate the effect of natural resources extraction on these two variables. This paper aims to analyze the long-run and short-run carbon dioxide emission and energy consumption effect of natural resources extraction in Ghana.

Design/methodology/approach – The theoretical foundation for this study is the Stochastic Impacts Regression on Population, Affluence and Technology (STIRPAT) model. Secondary Data sourced from World Development Indicators (2018) for the period of 1971-2013 were used. Estimation was done by using the autoregressive distributed lag.

Findings – It was found among other things that urbanization, and extraction of natural resources contribute to Ghana's carbon dioxide emission, while official development assistance helps in reducing carbon dioxide emission in the long run. Again, while income and extraction of natural resources increase energy consumption, urbanization and official development assistance reduce environmental degradation in the long run. Regarding the short run, income and urbanization both increase energy consumption and carbon dioxide emission; trade openness and official development assistance decrease both carbon dioxide emission and energy consumption.

Research limitations/implications – The implications from the results include the need to strictly enforce laws regulating extractive activities in the country to ensure a safe environment; and also to raise tariff and non-tariff barriers on products that do not promote a friendly environment and vice versa.

Originality/value – The effect of natural resources extraction on carbon emission and energy consumption is examined.

Keywords CO_2 emission, Ghana, Regression, Energy consumption, Mining, Co-integration, Natural resource, STIRPAT model

Paper type Research paper

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1. Introduction

Climate change has received global attention for the past decades because of its adverse effects on human life. A major contributing factor to the climate change menace is the emission of greenhouse gases of which carbon dioxide (CO_2) is the chief [Intergovernmental Panel on Climate Change (IPCC), 2001]. The global emission of carbon dioxide (metric tons per capita) has increased consistently over the years from about 3.1 in 1960 to 4.4 in 1980 and then to 5.0 by 2014 [World Development Indicators (WDI), 2018]. To address the issue of climate change, world leaders have devoted themselves to reduce CO_2 emission to help keep global temperature rise below the level of 2°C (Charfeddine *et al.*, 2018). Policymakers, environmentalists and researchers have therefore committed themselves to identify the possible drivers of CO_2 emission for a long while.

Owing to the fact that climate change is a global phenomenon that requires an "all hands on deck" approach to reduce CO_2 emission, empirical studies have been embarked upon for high CO_2 emitting countries (Alper and Onur, 2016), low CO_2 emitting countries (Kwakwa *et al.*, 2014), developed countries (Dogan and Ozturk, 2017) and developing countries (Asumadu-Sarkodie and Owusu, 2016a; Charfeddine *et al.*, 2018; Aboagye, 2017a; Aboagye and Kwakwa, 2014; Kwakwa and Adu, 2016; Asumadu-Sarkodie and Owusu, 2016b; Al-Mulali and Ozturk, 2016). Such studies have revealed a number of factors including energy consumption, population, trade and economic growth play a significant role in determining the level of CO_2 emissions for countries. That notwithstanding, there is the need for further studies to investigate the possible drivers of CO_2 emission for countries. This is because there have been conflicting results reported in the literature based on the period, the country of study and the methods employed in the previous studies. This could seriously affect policy and practical implications. Then again, not much attention has the previous studies given to estimate the possible effect of natural resource extraction on carbon dioxide emissions. Natural resources extraction can contribute to environmental degradation through the high energy consumption required for extraction and the indiscriminate disposal of waste chemicals into water, land and air. Owing to the effect energy consumption has on climate change via CO_2 emission (Asumadu-Sarkodie and Owusu, 2016a; Asumadu-Sarkodie and Owusu, 2016b) and the fact that many including Inglesi-Lotz and Morales (2017) regard high energy consumption as a deterioration of the environment it has become necessary to also identify the determinants of energy consumption in order to help reduce CO_2 emission (Destek, 2018).

The aim of this study is to examine the CO_2 emission and energy consumption effects of natural resources extraction activities in Ghana. Ghana is endowed with many natural resources including gold, diamond, forestry and oil. The contribution of natural resources to Ghana's growth and development process cannot be overemphasized. For instance, in 2015 forestry, mining and oil contributed respectively GH¢783m, GH¢ 2.7bn and GH¢ 2.1bn to Ghana's gross domestic product (Ministry of Lands and Natural Resources, 2016). This respectively translates into about 2.1, 7.3 and 5.5 per cent of gross domestic product at constant price [World Development Indicators (WDI), 2018]. In addition, the mining sector alone is said to directly employ over 14,000 people (Kim *et al.*, 2013) while supporting about over 100,000 jobs (Ghana Chamber of Mines and International Council of Mining and Metals, 2015). Although the extractions of natural resources dates back to the seventh and eight century AD (Fatawu and Allan, 2014), the increasing spate of illegal mining, illegal felling of trees and illegal fishing activities in the country have raised public outcry because of the environmental destruction in terms of land, air and water pollution associated with them (Hilson, 2002). Also, the indiscriminate disposal of waste chemicals by legalized mining and oil firms into river bodies has been documented by Fatawu and Allan (2014) and Hilson (2002) respectively.

Further, oil and mining firms are known for their high level of energy consumption which contributes to the emission of CO_2. Consequently, with the increasingly oil exploration activities in Ghana and the obvious future expansion in commercial production of oil; as well as the increasingly craze of small-scale mining activities in the country coupled with the expected increase in demand for precious minerals and metals, it will be necessary to estimate the CO_2 emission and energy consumption effects of such extractive activities. This will be helpful in designing the most efficient and cost-effective ways to achieve a low-carbon economy going into the future. It is in this light that this study examines the effect of natural resources extraction activities on carbon dioxide emission and energy consumption in Ghana.

This study makes a number of contributions to the literature. First, although studies like Fatawu and Allan (2014) and Hilson (2002) have narrated the effect of Ghana's natural resources extractive activities on land, water bodies and air, they do not employ any econometric tool to estimate the degrading environmental effect of such extractive activities as this study does. Second, previous studies (Asumadu-Sarkodie and Owusu, 2016a; Charfeddine *et al.*, 2018; Aboagye, 2017a; Kwakwa and Adu, 2016; Asumadu-Sarkodie and Owusu, 2016b; Al-Mulali and Ozturk, 2016) that have explored the drivers of CO_2 emission do not account for natural resources extraction. This study does that analysis. The paper also argues and includes natural resources extraction in estimating the drivers of energy consumption. This will help offer further guidelines to policymakers in designing appropriate policies to tackle the energy problem that has bedeviled the country. Indeed, works by researchers like Kwakwa (2018a) and Adom and Bekoe (2012) on Ghana's energy demand and supply situation have indicated the country's energy situation deserves some ample attention.

The remainder of the paper is structured as follows: Section 2 reviews the literature. Section 3 describes the method and data used. Section 4 discusses the main findings of the study. Section 5 concludes with policy recommendations.

2. Literature review

This section of the paper is devoted to reviewing theoretical and empirical issues related to the study. We begin by looking at the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model; and follow it up with evidence of empirical studies that have examined the drivers of energy consumption and carbon dioxide emission within the STIRPAT model, largely. The Environmental Impact (I), Population (P), Affluence (A) and Technology (T), (IPAT) equation with its modifications has been the longest held view among theories and models to analyze the effect of human activities on the quality of the environment. This equation attributed to Ehrlich and Holdren (1971), and Commoner (1972) argues that environmental impact depends on the levels of population, affluence and technology. Thus, a growing population rate would put pressure on the environment to meet societal needs – the building of houses, water, transportation, energy and food – that may deteriorate the quality of the environment. A high level of affluence also may negatively affect the environment as there would be an increase in the consumption level of the economy; there would be stress on natural resources; and increasing demand for electrical and other high energy consuming machines. A high level of affluence is also associated with the generation of wastes and pollution. The level of technology (the different ways in which societies use their productive resources), can also have a significant effect on the degree of environmental impact, either reducing it or enlarging it.

Dietz and Rosa (1994) modified the IPAT equation to the Stochastic Impacts by Regression on Population, Affluence and Technology (STIRPAT) model by introducing a stochastic term to the IPAT equation. This modification allows for hypothesis testing and estimation of the non-proportional effects from the driving forces of the environment. Accordingly, the STIRPAT model has been employed by many researchers including Behera and Vishnu (2011), Uddin *et al.*

(2016), Hassan (2016), Li and Lin (2015) and Shahbaz *et al.* (2015) to investigate the possible factors of carbon emission for countries. Others including Wang and Han (2016), Inglesi-Lotz and Morales (2017), Salim and Shafiei (2014) and Ma *et al.* (2017) have also used the STIRPAT model to estimate the drivers of energy consumption. The results from all these studies have not been uniform. For instance, on carbon emission studies, Li and Lin (2015) obtained a positive effect from population, income, urbanization, industrialization and energy intensity on carbon emission. For the economy of Bangladesh, Hassan (2016) found that the emission effects of income, urbanization and technology are positive. Shahbaz *et al.* (2015) observed a long-run positive effect of income, energy and trade openness on carbon emission. In their study, Wang *et al.* (2011) found population size, affluence and urbanisation to positively affect carbon emission, while energy intensity is recorded to have a negative effect on carbon emission for Minhang District, Shanghai China. Martínez-Zarzoso (2008) investigation indicated CO_2 emission is increased by income, population and industrialization while energy efficiency reduces it.

In his analysis of the effect of urbanization and affluence on carbon emission for 31 developed/OECD countries and 54 developing/non-OECD countries, Liddle (2011) reported that affluence, urbanization and share of electricity increase CO_2 emission. For the Chinese economy, Sheng and Guo (2016) examined the effects of population, affluence, technology and urbanization on CO_2 emission for 30 provinces in China between 1995 and 2011. In the long run, the authors found an inverted U-shaped relationship between environmental regulation and carbon emission; a positive effect from industrial structure, urbanization and income on CO_2 emission; and a negative effect of population on CO_2 emission. In his study for a panel of emerging economies, Sadorsky (2014) found that urbanization reduces CO_2 emission while income, energy intensity and population increase CO_2 emissions. The effect of urbanization was a mixture of positive and negative. For sub-Saharan African countries, Amuakwa-Mensah and Adom (2017) used the STIRPAT model and report of the positive effects of globalization and forest size on carbon emission but a negative effect of energy efficiency on carbon emission. A study on Ghana by Adams *et al.* (2016) under the model concluded that income, trade openness and institutional quality reduce CO_2 emission while urbanization increases it.

Other carbon emission studies on Ghana and elsewhere that did not apply the STIRPAT model including Aboagye (2017b), Kwakwa *et al.* (2014), Twerefou *et al.* (2016) and Ozturk and Al-Mulali (2015) also noted the significant effect of income, urbanization, industrialization and trade openness among others on CO_2 emission. For instance, Ozturk and Al-Mulali (2015) found that trade openness, and urbanization exert a positive effect on CO_2 emission while corruption control and effectiveness of government exert a negative effect on CO_2 emission. Also, Kwakwa *et al.* (2014) recorded a non-linear relationship (an inverted U shape relationship) between both agriculture and industrialization, and CO_2 emission in Ghana. Aboagye (2017b) confirmed the environmental Kuznets curve (EKC) hypothesis and also found that urbanization, population, foreign direct investment, industrialization positively affect Ghana's CO_2 emission in the long-run. Adom *et al.* (2018) among many things revealed energy price and financial development reduce CO_2 emission while urbanization increases CO_2 emission in Ghana. Kwakwa and Alhassan (2018) also found urbanization and industrialization to exert a positive effect on CO_2 emission; a negative effect of trade and hydropower on carbon emission; and a confirmation of the EKC hypothesis in Ghana.

With regards to energy consumption studies that employed the STIRPAT model, Wang and Han (2016) found that research and development, income, investment in ICT and population reduce energy intensity in China. Inglesi-Lotz and Morales (2017) among other things reported a positive effect of population, industrial share and income on energy consumption. Shahbaz *et al.* (2017) also recorded that income, technology and transportation increase energy consumption for Pakistan. In their work, Shahbaz *et al.* (2015) obtained a positive significant effect of economic growth, capital stock, energy and trade on the emission of CO_2, but a U-shaped relationship between urbanization and CO_2 emission. Salim and Shafiei (2014) also reported that population and urbanization positively influence non-renewable energy consumption while population density has a negative impact on non-renewable energy consumption.

Zongjie *et al.* (2016) also extended the STIRPAT model to examine energy consumption in a hotel. They reported that occupancy rate, a unit area of revenue, and unit revenue of energy consumption positively increase energy consumption, but temperature can decrease energy consumption. In their study, Yang *et al.* (2018) among others also found that urbanization, population, energy intensity, trade openness, cooling degree days and mean temperature anomaly increased CO_2 emissions for China. Ma *et al.* (2017) reported that population, urbanization rate, floor area per capita of existing Chinese commercial buildings, GDP index in the Chinese tertiary industry sector, and energy intensity have a positive effect on Chinese commercial building energy consumption.

In the Ghanaian literature, the works by Kwakwa (2012), Adom and Kwakwa (2014), Kwakwa and Aboagye (2014), Kwakwa *et al.*, 2015; Kwakwa *et al.* (2013); Mensah and Adu (2013); Adom and Bekoe (2013), Adom and Bekoe (2012); Adom (2011); Adom *et al.* (2012); Adom (2013); and Aboagye (2017b) revealed that a number of factors influence energy consumption at the micro and macro level although their empirical studies were not done within the STIRPAT framework.

At the micro level, Mensah and Adu (2013) noted that the probability of using clean and efficient fuels over the inefficient fuels is negatively influenced by household size, the age of the household head and male households heads while education has the opposite effect. Kwakwa *et al.* (2013) among other things found households' charcoal usage is reduced by income and employment. Also, Kuunibe *et al.* (2013) found a negative relationship between biomass usage and the level of education, income and relative price while the opposite was observed for household size.

At the macro level, the study of Adom and Bekoe (2012) reported that Ghana's electricity consumption is positively influenced by industrial output, urbanization and income; but negatively influenced by industrial efficiency. In another study, Adom (2013) found a positive relationship between income and electricity consumption. However, energy efficiency and economic structure were found to reduce electricity consumption. In their work, Kwakwa and Aboagye (2014) also reported Ghana's long run energy consumption is positively affected by trade openness and urbanization but reduced by income. Adom and Kwakwa (2014) revealed that technical characteristics of the manufacturing sector and production mix reduce Ghana's energy intensity but export and urbanization exert a positive effect. The study by Aboagye (2017b) on the drivers of energy consumption and energy intensity in Ghana have also reported of an inverted U-shaped relationship between income and energy consumption; positive effect of urbanization, trade and industrialization on energy consumption; and a negative effect of foreign direct investment on energy consumption.

The conclusion from the above review is that although much is talked about CO_2 emission and energy consumption in the literature, there is little to no studies conducted that uses econometrics to estimate the effect of natural resource extraction on these environmental indicators. The current study, therefore, seeks to bridge this gap.

3. Methodology and data

3.1 Theoretical and empirical specification

The theoretical foundation for this study is the Stochastic Impacts Regression on Population, Affluence and Technology (STIRPAT) model. As indicated in Section 2, Dietz and Rosa (1994) modified the IPAT equation to the STIRPAT model to estimate the environmental impact of affluence, population and technology by introducing a stochastic term. Mathematically, the model is expressed as below:

$$I_t = \alpha P_t^{\beta_1} A_t^{\beta_2} T_t^{\beta_3} \varepsilon_t \quad (1)$$

where α is a constant term, I is an environmental impact, P is population, A is affluence, T represents technology, βs are the parameters to be estimated, ϵ is the stochastic term and t represents the period.

In many empirical studies, environmental impact has been represented by CO_2 emission and energy consumption. Income has been used to denote affluence while total population and or urbanization have been used to describe the population. The level of technology which is the efficient transformation of inputs has been denoted by a number of variables of which trade openness is key. The argument is that trade openness enhances the transfer of advanced technology from the developed world towards emerging and developing economies (Shahbaz *et al.*, 2016). This is met through the importation of technology which makes advanced technology available for efficient production or through foreign direct investment (FDI) which promotes technological development through the diffusion of technology from developed countries to the host developing countries. Ghana, like many developing countries, lags behind in terms of modern or state-of-the-art technology for production. However, importation of technology and the inflows of foreign direct investment via trade openness have helped to transfer advanced technology to the country which promotes efficiency. Nevertheless, the literature makes mention of the pollution haven hypothesis (PHH) which posits that trade openness negatively affects the environmental quality of developing countries since in their bid to attract foreign firms; they are compelled to reduce the environmental standards thereby allowing foreign firms to operate with sub-standard technology.

According to the National Communications Authority (2017), the value of Ghana's information and communications technology (ICT) imports increased from GH¢ 767.4 million in 2010 to GH¢ 1,118.3 million in 2015 although the share of ICT imports to total imports reduced from 6.2 per cent to 2.4 per cent at the same period. Further, the WDI (2018) has indicated that the level of Ghana's net FDI (per cent of GDP) has increased in recent times averaging 7.92 per cent from 2007-2017 compared to less than 3 per cent from 1997 to 2007. This makes it necessary to examine the effect of trade openness on Ghana's quality of environment especially energy consumption and emission of carbon dioxide. Previous studies including Amuakwa-Mensah and Adom (2017) and Kwakwa (2018b) were motivated by a similar argument to use trade openness to capture technology in their carbon dioxide and energy consumption studies respectively.

Since the nature of equation (1) above allows the model to be modified, significant variables worth considering are included in the equation. Accordingly, we include natural resource extraction (N) into the model. The inclusion of natural resource extraction is on the grounds that it can contribute to environmental degradation through the high energy consumption required for extraction and the indiscriminate disposal of waste chemicals into the environment. A report by the IEA shows that 6.9 per cent of the total energy (Mtoe) produced by the oil and gas industry was consumed by the same industry (Parekh and Singh, 2015). Further, the process of flaring natural gas also produces greenhouse gases like carbon dioxide which degrades the environment (Reporting oil and Gas, 2016). To ensure the adequacy of the results, we control for development assistance (D). Taking the above into consideration yields equation (2):

$$I_t = \alpha P_t^{\beta_1} A_t^{\beta_2} T_t^{\beta_3} N_t^{\beta_4} D_t^{\beta_5} \varepsilon_t \quad (2)$$

To interpret the estimated parameters as elasticities, the natural log of each variable in equation (2) is taken and represented as:

$$\ln I_t = \delta + \beta_1 \ln P_t + \beta_2 \ln A_i + \beta_3 \ln T_t + \beta_4 \ln N_t + \beta_5 D_t + \xi_t \quad (3)$$

Thus, we rely on the STIRPAT model to estimate the effect of urbanization, affluence, trade openness, development assistance and natural resource extraction on carbon emission and energy consumption for the Ghanaian economy.

3.2 Estimation strategy

To avoid spurious results from estimating equation (3), the study examines the stationarity of the variables to ensure they contain no unit root at least at first difference. In doing so, the augmented Dickey–Fuller (ADF) and the Phillips–Perron (PP) tests, respectively developed by Dickey and Fuller (1979) and Phillips and Perron (1988) for the stationarity test are employed. The strength of these tests is that, the ADF has the ability to deal with the problem of serial correlation and heteroscedasticity in the residuals through the use of parametric autoregression and the PP uses non-parametric methods to correct for any serial correlation and endogeneity of regressors. However, since both the ADF and PP approaches can be biased in the presence of structural breaks in the time series, the Zivot and Andrews (ZA) unit root test which allows for unknown breaks is used to further check for the stationarity of the variables.

After this, the existence of level (cointegration) relationship between environmental degradation (energy consumption and carbon emission) and their respective determining factors is tested by relying on the bounds testing approach within the autoregressive distributed lag (ARDL) framework. The main advantage of this method is that it can be applied independently whether the regressors are 1(0) or 1(1) and avoids the pre-test with standard cointegration. The Johansen, Engle–Granger and the Phillips–Ouliaris Tests are used to confirm the long-run relationship. Finally, we estimate the short and long run multipliers of energy consumption and CO_2 emission from equation (3) using the popular ARDL cointegration technique.

3.3 Data description and source

This study used annual time series data covering 1971-2013 sourced from WDI (2018) database. The selection of this period was influenced by data availability. The environmental impact which is our dependent variable in this study is measured using two variables namely, emission of CO_2 (kt), and Energy use (kg of oil equivalent per capita) (ENER). Also, population is represented by urban population (per cent of total) (URB), affluence (income) is represented by adjusted GDP (YN) [i.e GDP current local currency divided by GDP deflator], trade openness is represented by the sum of import and export as a share of GDP (TO), and natural resource extraction is measured by total natural resources rents (per cent of GDP) (NAR). Development Assistant is represented by net official development assistance (ODA) received (per cent of gross capital formation).

Table I shows the descriptive statistics of the annual time series data covering the period 1971 to 2013 where for instance, the mean of energy consumption is 345.61 kg, while the average of carbon dioxide emission per capita is 5387.16 kt. However, natural resources rents as a percentage of GDP has a mean of 8.82. Trade as a share of GDP has a mean of 55.61, while the average adjusted GDP per capita is GH¢ 99,700,174. The urbanization share of total population has a mean value of 38.95 per cent, while the average of official development assistance as a share of capital formation is 49.68 per cent.

4. Empirical results

This section presents and discusses the empirical results under unit root and cointegration analysis, and short and long-run estimates.

4.1 Unit root and cointegration analysis

To determine the stationarity of the variables as well as the long-run relationship among them the unit root and cointegration tests were run. The stationarity of each variable was checked using the PP, ADF and ZA tests. The results presented in Table II indicate that at levels, the PP test accepts the presence of unit root for all the variables while the ADF test accepts the presence of unit root for all the variables except lnYN and lnURB. However, at first difference all the other variables become stationary, except lnURB. This implies that lnYN and lnURB are integrated of order zero, I(0) and all the other variables are integrated of order one, I(1). The Zivot and Andrew Unit Root test results presented in Table III indicate that stationary is attained for all the series despite the presence of structural break[1]. This means estimation can be done with the series without getting spurious results.

Statistics	CO_2	ENER	YN	URB	TO	NAR	ODA
Mean	5387.164	345.6082	99700174	38.94628	55.61085	8.819504	49.68435
Median	3982.362	359.8670	75177181	37.90500	45.99360	7.749342	45.08089
Maximum	14620.33	415.6502	2.76E + 08	52.74800	116.0484	19.93034	103.1460
Minimum	2295.542	269.1488	29362525	29.17400	6.320343	2.335510	9.617632
SD	2975.770	38.86726	62135833	7.695054	29.99911	3.995608	23.42446
Jarque–Bera	9.007084	2.395232	14.71025	3.787290	2.287926	6.126378	2.494237
Probability	0.011070	0.301913	0.000639	0.150522	0.318554	0.046738	0.287331
Observations	43	43	43	43	43	43	43

Table I.
Descriptive statistics

	PP		ADF	
Variables	Intercept	Intercept and trend	Intercept	Intercept and trend
At levels				
$lnCO_2$	1.7936	−3.0618	0.7993	−3.2224
lnYN	0.7160	−3.1363	1.3707	−3.3501*
lnURB	2.6328	−3.008	0.0814	−3.6237**
lnTO	−0.7040	−2.1062	−0.7075	−2.0575
lnNAR	2.0929	0.9035	1.7967	0.0366
lnENER	−1.8461	−2.2772	−1.6516	−2.0434
lnODA	−2.4736	−2.4495	−2.5257	−2.6480
At first difference				
$lnCO_2$	11.3025***	−27.2037***	−9.5250****	−9.6829***
lnYN	−9.4225***	−13.4992***	−9.4225***	
lnURB	−1.5045	−1.0987	−1.7066	
lnTO	−5.7037***	−5.6689***	−5.5108***	−5.4937***
lnNAR	−5.9354***	−7.9791***	−5.8600***	−7.4743***
lnENER	−5.9696***	−5.8932***	−5.9759***	−5.9005***
lnODA	−8.5071***	−8.6609***	−8.5281***	−8.6541***

Note: ***, ** and * denotes 1, 5 and 10% level of significance, respectively

Table II.
Unit root test results

Table IV presents the results of the cointegration tests based on the ARDL bounds cointegration and the Johansen test which shows that the null hypothesis of no co integration is rejected for both energy and CO_2 models. For robustness, the Engel–Granger, Phillips–Ouliaris and Hansen cointegration tests results reported in Table V confirmed there is co integration. The Engel–Granger cointegration and the Phillips–Ouliaris tests reject the null hypothesis of no cointegration for both the CO_2 and the energy models, while the Hansen cointegration test accepts the null hypothesis of cointegration for both the CO_2 and the energy models. We conclude there is the existence of long-run relationship between the selected dependent variables and the set of explanatory variables. The Akaike Information Criterion (AIC) was used to select optimal lag for cointegration, as it tends to give a model that has a good fit to the data (Akaike, 1973; Burnham and Anderson, 2002). An optimal lag length of four was selected by the AIC.

4.2 Discussion of short and long-run relationship

The results of the long-run and short-run ARDL estimates for CO_2 and energy consumption models are reported in Tables VI and VII, respectively. Based on the results, natural resource extraction, urbanization and official development assistance significantly affect

Table III. Zivot ANDREW unit root test

Variables	Intercept and trend (Breakpoint)	Trend (Breakpoint)
$\ln CO_2$	−5.818*** (1988)	−5.3736*** (1988)
lnYN	−4.5382** (1979)	−5.9235 (1984)
lnURB	−3.33558 (2006)	−3.3995*** (2005)
lnTO	−3.7840*** (2001)	−3.5319*** (2001)
lnNAR	−4.3214** (2001)	−3.9238 (1989)
lnENER	−3.9110*** (2000)	−2.0270 (2007)
lnODA	−5.7188** (1992)	−4.6442** (1983)

Note: *** and ** denotes 1, and 5% level of significance, respectively

Table IV. Cointegration test

	ARDL test			Johansen test	
Series	*F*-test statistic	I(0)	I(1)	Trace stat.	No. of co integration
CO_2 model	6.4137***	3.29	4.37	99.49**	None
Energy model	6.3061***	3.06	4.15	69.81**	At most 1

Note: *** and ** denote 1 and 5% level of significance

Table V. Engel–Granger, Phillips–Ouliaris and Hansen cointegration tests

	Engel-Granger *H0.* There is no cointegration		Phillips-Ouliaris *H0.* There is no cointegration		Hansen *H0.* There is cointegration	
Series	tau-statistic	*z*-statistic	tau-statistic	*z*-statistic	Lc -statistic	Probability
CO_2 model	−6.4287***	−43.8877***	−6.5023***	−42.3635***	0.1138	0.2
Energy model	−4.7085	−30.2687*	−4.7896**	−30.7943*	0.0394	0.2

Note: ***, ** and * denotes 1, 5 and 10% level of significance, respectively carbon dioxide emissions, while natural resource extraction, urbanization and official development assistance influence energy consumption in the long run. In the short run, however, income, urbanization, trade openness and official development assistance significantly affect energy consumption, while income, urbanization, official development assistance and trade openness influence carbon dioxide emissions. The coefficient of the lagged ECT term (Table VII) is negative and significant at 1 per cent for both the energy and carbon dioxide emissions models, suggesting that when energy consumption and carbon dioxide emissions are above, or below equilibrium level, it adjusts by 29 and 94 per cent, respectively within the first year.

4.2.1 Environmental effect of income. From Table VI income is seen to exert a positive effect on energy consumption but has no significant effect on carbon dioxide in the long-run. The results imply that a 1 per cent increase in GDP increases energy consumption by 0.71 per cent in the long-run. This is reasonable because as the economy grows, the demand for high energy consuming products also increases which increase the consumption of energy. Further, as income increases, more energy is needed to produce more goods for meeting the rising demand.

In recent times, the appetite of Ghanaians for vehicle and other energy consuming products seems to have increased. As people's income rises, they think to acquire for

	Energy consumption		Carbon dioxide emission	
Variable	Coefficient	*t*-statistic	Coefficient	*t*-statistic
lnYN	0.7134**	2.3967	0.0879	0.6001
lnNAR	0.3604***	2.7614	0.1858**	2.0673
lnURB	−3.0525***	−3.3445	2.0824***	4.1760
lnTO	−0.1189	−1.2009	−0.0561	−0.9290
lnODA	−0.1596*	−1.7058	−0.1483**	−2.3855
Constant	3.6466	1.4306	−0.4265	1.4038

Notes: ***, ** and * denotes 1, 5 and 10% level of significance, respectively; Model selection for each model was ARDL(1,1,1,1,1,1)

Table VI. Long run estimates of energy consumption and carbon dioxide emission

	Energy consumption		CO_2 emission	
Variable	Coefficient	*t*-Statistic	Coefficient	*t*-Statistic
DlnYN	0.0666*	1.9283	0.1530*	1.9875
DlnNAR	0.0237	0.8347	0.0407	0.6924
DlnURB	11.4672***	7.3495	15.7256*	1.9083
DlnTO	−0.1240***	−4.6080	−0.0653	−1.0628
DlnODA	−0.0269*	−1.7664	−0.1086***	−3.1722
DlnYN(-1)			−0.0815	−1.1323
DlnNAR(-1)			−0.0289	−0.4532
DlnURB(-1)			−7.4231	−0.8863
DlnTO(-1)			−0.1651**	−2.7699
DlnODA(-1)			−0.0248	−0.7327
ECT(-1)	−0.2907***	−5.5877	−0.94***	−5.3724
Adj *R*-squared	0.59		0.68	
DW-stat.	2.16		1.72	

Notes: ***, ** and * denotes 1, 5 and 10% level of significance, respectively; Model selection for energy model was ARDL(1,1,1,1,1,1) and ARDL(1,2,2,2,2,2) for CO_2 model

Table VII. Error correction for the ARDL models themselves items that will make life a little more comfortable for them. Hence, it is not uncommon to see people buy vehicles for their private use and washing machines among other things when they see an appreciable rise in their incomes. Others also purchase vehicles for commercial use with the aim of earning extra income. The result is the increasing number of cars imported into the country which ultimately leads to an increase in the level of energy consumption and indirectly rising CO_2 emissions. This finding is consistent with that of Shahbaz *et al.* (2017). Previous studies in Ghana such as Adom (2011), Adom and Bekoe (2013) and Adom and Bekoe (2012) have already indicated income positively affect electricity consumption for the country.

In the short run, however, income increases energy consumption and carbon dioxide emission (Table VII). Thus, the short-run effect of income on energy consumption is similar to its long-run effect. However, the positive effect of income on CO_2 emission in the short run implies that as the economy expands, the early stages of transformation pollute the environment and thus, the income-inducing emission effect is short-lived hence the positive (insignificant) effect of income on CO_2 emission in the short run (long run).

4.2.2 Environmental effect of natural resource extraction. The elasticity of CO_2 with respect to natural resource extraction is positive in the long run (Table VI) but insignificant in the short run (Table VII), suggesting that a 1 per cent increase in natural resource extraction increases CO_2 emissions by 0.19 per cent in the long run. It is possible to attribute the environmental degrading effect of natural resource extraction in Ghana to the mining activities, forestry activities and the increasing oil exploration in the country. Owing to the environmental degrading effect of mining in some mining communities in the country, there has been a protest by some group of people in the Atewa Landscape of Ghana to persuade the government of Ghana to abort its decision to give out the Atewa Forest Reserve in the Eastern Region for bauxite mining. Their concerns include the fact that the Ayensu, Densu and Birim rivers that supply water to over five million people in the country will be affected. Again, they argue that an "estimated current annual values of non-timber products of US$12.4m, climate amelioration services of 55,000 tonnes of CO_2 per year, potential tourism revenue over US$5m, cocoa production at US$9.3m, and timber at US $40.6m" (Environmental News Agency, 2018), will be lost. To demonstrate their seriousness, the group embarked upon a 95 km walk from Kyebi to Accra to petition the president.

In the case of oil and gas exploration, the environmental effect comes from many angles. For instance, since Ghana started commercial production of oil in 2011, Reporting oil and Gas (2016) has indicated that the burning of natural gas to dispose of gas produces nitrogen dioxides, CO_2 and photochemical oxidants degrade the environment. In addition, the increasing oil exploration consumes a high level of energy which emits CO_2. Also, "power generation and flaring of hydrocarbons during well testing and clean-up operations meant to ensure safety at the platform" (Reporting oil and Gas, 2016, p. 6) have been found to pollute the environment. Moreover, the extraction of forest resources through felling of trees reduces the vegetational cover which could absorb CO_2 emission hence higher CO_2 emission.

With regards to the energy model, the estimated coefficient also shows that natural resource extraction increases energy consumption in the long run, while the short run coefficient on natural resource extraction is not statistically significant. The continuous extraction of natural resources depends largely on energy without which equipment for such extractive activities would be difficult to function. Thus, as extraction activities increase, energy consumption also increases. The coefficient implies that an increase in natural resource extraction activities by 1 per cent will increase energy consumption by 0.36 per cent in the long term. It is an indication for authorities to pay attention to natural resource extractive activities when drawing plans to deal with the countries energy security issues.

The insignificant effect of natural resource extraction on energy consumption and CO_2 emission in the short run suggests that the extraction of natural resources do not exert an immediate harmful effect on the environment.

4.2.3 Environmental effect of urbanization. The results inform that a 1 per cent increase in urbanization rate increases CO_2 emissions by about 2.08 per cent (15.73 per cent) in the long term (short term) implying that urbanization has environmental degradation effect in Ghana. In 2010, Ghana for the first time ever saw an estimated 51 per cent of its population living in town and cities (Ghana Statistical Service, 2013). The rapid pace of urbanization is rippled with many challenges including heavy vehicular traffic resulting in a continuous increase in fossil energy consumption and the clearing of vegetation cover to build infrastructure to meet the needs of the growing urban population. Consequently, this phenomenon may reduce environmental quality via CO_2 emissions. In addition, the current uncontrolled urbanization in the country has led to an increase in waste generation both solid, liquid and air which has outpaced the capacity of local government to manage it sustainably; such that Ghana is ranked among the dirtiest place in Africa (Blacksmith Institute, 2013). The result is consistent with those of Kwakwa and Adu (2016), Adams *et al.* (2016) and Amuakwa-Mensah and Adom (2017).

Urbanization is also found to have a statistically significant positive (negative) effect on energy consumption in short run (long run). The positive significant effect on energy consumption suggests that urbanization increases energy consumption in the short term since rapid urbanization increases the consumption of goods and service, which requires energy for the production process. Furthermore, the construction, operation and maintenance of urban infrastructure such as the transport system increase the consumption of energy. However, the high energy consumption is short-lived as it was observed that urbanization reduces energy consumption in the long run. This can be attributed to the use of energy efficient technology and eco-friendly practices that enhances environmental quality which supports the ecological modernization and the compact theories.

4.2.4 Environmental effect of trade openness. From the results, trade openness is found to reduce CO_2 emissions in the short run (Table VII) but has no significant effect in the long term (Table VI). The effect of trade on the environment as argued in the literature is not straightforward. Proponents of the Pollution Haven Hypothesis (PHH) argue that trade openness negatively affects the environmental quality of poor countries since in their bid to attract foreign firms; they are compelled to reduce the environmental standards. The consequence is that negative externality sets in, to the detriment of the poor host country (Neumayer, 2004). It also deteriorates the environment by encouraging countries to extract more of resources that do not have a well-defined property right (Chichilnisky, 1994). Trade openness also affects the quality of the environment through its scale effect, composition effect and technique effect (Erickson *et al.*, 2013). This suggests that the environmental improving effects of trade outpace the deteriorating effects of trade on the environment in the case of Ghana. The result is in consonance with that of Adams *et al.* (2016) and Wang *et al.* (2011). Regarding energy, trade is found to have a reducing effect on energy consumption in the short run. Thus, trade promotes the transfer of advanced and efficient technology which ensures efficient energy usage in the short run. The result is in tandem with that of Kwakwa *et al.* (2018).

4.2.5 Environmental effect of official development assistance. The elasticity of CO_2 with respect to official development assistance is negative in the short and long run. This suggests that official development assistance in the form of financial and technical support enhances the capacity of developing countries to adopt higher environmental standards which ensure environmental clean-up and preservation. The result confirmed the observation made by Kablan (2018). Official development assistance was also found to have a reducing effect on energy consumption in the short and long run. Thus, it encourages efficient energy usage through investment in energy efficient technology. The result is consistent with that of Kretschmer *et al.* (2013) who argued that aid reduced energy intensity of GDP in recipient countries.

4.3 Diagnostic tests and sensitivity analysis

The study runs various diagnostic tests namely, test for serial correlation, heteroscedasticity, normality and functional form. The results obtained are shown in Table VIII and it is seen that both the energy consumption and CO_2 emission models are correctly specified as the p-values for serial correlation, normality, heteroscedasticity and functional form are statistically insignificant. This implies that the null hypothesis of no serial correlation, normally distributed residuals, homoscedasticity and correct functional form are not rejected at 5 per cent and hence the models are adequate and robust.

4.4 Causality analysis

The study went ahead to employ the vector error correction model (VECM) Granger causality method to determine the causal relationships between variables and results are reported in Table IX.

Table VIII. Diagnostic tests and sensitivity analysis

Diagnostic statistics		Energy consumption Test statistic	Carbon dioxide emission
Serial correlation	Breusch–Godfrey	F-stat.: 0.2732 (0.7628) Obs*R^2: 1.5760 (0.4547)	F-stat.: 1.4166 (0.2583) Obs*R^2: 1.9170(0.3835)
Normality	Jarque–Bera	2.2033 (0.3321)	3.3942 (0.1832)
Heteroscedasticity	Glejser	F-stat: 0.7334(0.6987) Obs*R^2: 8.9013(0.6310)	F-stat: 0.7010(0.76644) Obs*R^2: 13.0581 (0.6685)
Functional form	Ramsey Reset	F-stat: 0.0022 (0.9626)	F-stat: 1.6781(0.2080)

Note: Probability in parenthesis

Table IX. VECM Granger causality

Equation	Short run DlnCO$_2$	DlnYN	DlnNAR	DlnURB	DlnTO	DlnODA	Long run ECT (−1)
DlnCO$_2$		12.9185***	8.2548***	8.3944***	7.8966**	18.5697***	−3.8040***
DlnYN	0.7944		2.8944	2.2194	2.1687	1.0423	0.9707
DlnNAR	1.6797	3.6384		0.8213	0.4468	2.6967	1.8782
DlnURB	4.6203	10.3489**	3.5470		8.9531**	1.2024	−0.8223
DlnTO	2.4724	0.5349	3.3072	12.5366***		2.3659	0.6133
DlnODA	2.4778	9.5710**	7.7830*	12.7754**	2.0782		3.8835***
	DlnENE	DlnYN	DlnNAR	DlnURB	DlnTO	DlnODA	ECT (−1)
DlnENE		1.2502	4.6623*	6.6578**	4.5148	2.3938	−3.1729***
DlnYN	0.9428		5.5253*	0.2085	1.6751	1.6848	0.6735
DlnNAR	11.8853***	5.8550*		8.5131**	1.8218	0.5212	3.3314***
DlnURB	10.8510***	0.0498	3.1203		5.6680*	0.2234	−1.409
DlnTO	2.2864	0.1950	2.3885	10.1588***		3.4567	1.0926
DlnODA	2.0406	0.7222	0.5038	0.9317	1.4226		0.6628

Notes: ***, ** and * denotes 1, 5 and 10% level of significance, respectively; Chi-square values are reported for short run causality, while t-statistic values are reported for long run causality

For the carbon dioxide emission model, the results among others reveal unidirectional causality from income, natural resource, trade, urbanization and official development assistance to carbon dioxide emission in both short and long run periods. This implies effort to curb carbon emission by implementing policies that may influence income, urbanization, natural resource extraction and official development assistance would not have any feedback effect. Regarding the energy consumption model, there is a support for bidirectional causality between energy consumption and natural resource rent for both short and long run periods; and between urbanization and energy consumption. Thus, policies aimed at reducing energy consumption through urbanization and natural resource extraction may have some reverse effects on urbanization and natural resource rent.

5. Conclusion and policy implications

This study examines the long-run effect of natural resources extraction activities on carbon dioxide emission and energy consumption in Ghana under the Stochastic Impacts by Regression on Population, Affluence and Technology model for the period of 1971-2013. The motivation was as a result of the fact that previous studies on the drivers of environmental degradation especially CO_2 emission have done little to econometrically estimate the impact of natural resource extraction. Owing to the recent public outcry of the environment effect of natural resource extraction activities as well as the energy security issues in Ghana, the study relied on Ghana's data to examine the effect of natural resources extraction activities on CO_2 emission and energy consumption in the country. The ARDL method was used to estimate the short and long-run determinants of energy consumption and CO_2 emission. The results reveal that urbanization, official development assistance, trade, income and natural resource extraction have significant influence on carbon emission and energy consumption. The VECM results also show feedback effects in the long and short run relationships between energy consumption, and natural resource and urbanization while a unidirectional causality is observed from income, natural resource, trade, urbanization and official development assistance to CO_2 emission.

The findings from this study have policy implications. First, income and urbanization were found to increase carbon emissions and energy consumption. Probably, as a first step, local authourities should educate urban dwellers to use eco-friendly products and consume responsibly since this has the tendency to reduce the excessive deforestation and destruction of land in order to meet the high demand of goods and services of consumers. This will control natural resource extraction and thus promote environmental quality. In addition, the government should incentivize manufacturers to develop and design eco-friendly products which will not degrade the environment. To promote peaceful co-existence within the ecosystem, conservation practices such as planting of trees in the urban centres should be encouraged by the local government.

Since natural resource extraction activities degrade the environment, it is recommended that the EPA, Forestry Commission and Ministry of Local Government and Rural Development should not only educate companies that extract natural resources on the importance of afforestation nor encourage them to practice land reclamation and afforestation but also, they should enforce the laws regarding such practices in the country to ensure a safe environment. Per the current developments in Ghana regarding the extraction of natural resources especially mining and felling of timber, it clearly shows there is weak enforcement of the laws. The law enforcement agencies appear weak since they are under-resourced to perform their duties. In cases where offenders are even prosecuted the snail pace in the trial process and sometimes the punishment meted to the offenders are not deterrent enough. It is important for the punishment to be revised and made more deterrent.

In addition, policymakers need to pay attention to natural resources extractive activities in dealing with the country's energy security issues. It is recommended that the government facilitates to enable natural resources extractive firms to acquire and use eco-friendly energy and efficient equipment in their activities. The paper finds trade reduces CO_2 emission and thus recommends that it is needful for authorities to raise tariff and non-tariff barriers on products that do not promote a friendly environment whiles reducing tariffs on products that promote a quality environment.

Note

1. It is seen that the year 1988 is the most significant break-year for carbon dioxide emission, while the year 1979 emerges as the break-year for income. The break-point for trade openness and natural resource rent is detected at the year 2001. Also the break-points for official development assistance are observed at the year 1992 and 1983. The results identify a trend break in urbanization and energy consumption in the year 2005 and 2000 respectively. The structural breaks at these years are not strange since they are associated with the economic performance and some reforms Ghana has witnessed. The 1979 break in income can be linked to the military coup d'etat with the forceful transfer of authority from democratic rule to military rule headed by Flight Lieutenant Jerry John Rawlings. Thus, the fragile political instability accompanied with strict fiscal and quantitative controls may slow down economic growth (Jong-a-Pin, 2009). In 1983, Ghana implemented the structural adjustment programme to restructure and stabilize the economy. As part of the structural adjustment programme in 1983 policies including trade openness and financial reforms might have affected the level of carbon emission in 1988. The structural problems and economic decline in 1983 and 1992 could explain the break in 1983 and 1992 in official development assistance. In 2000, Ghana recorded its lowest real GDP growth rate after the implementation of the structural adjustment programme in 1983 and this could be the reason behind the break in the energy consumption for the year. The break in trade at 2001 can be linked to the effect of the trade policy adjustment that took place in 2000 including tariffs increment and the re-introduction of special imports tax (Nomfundo and Odhiambo, 2017). The break for natural resource rent for the same period can be due to the fall in prices of Ghana's primary –export commodities such as gold and cocoa (OECD/AfDE, 2002). In 2005, the government announcement plans to start youth employment programme to reduce the youth unemployment. This encouraged rural-urban migration in Ghana in order to benefit from the programme which started in 2006 (Coulombe *et al.*, 2012) hence, the break witnessed for urbanization in 2006.

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