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Abstract: 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 study analyzes the long run environmental effect of natural resources extraction in Ghana under the Stochastic Impacts by Regression on Population, Affluence and Technology model for the period of 1971-2013. Estimation results indicate that income, urbanization, and extraction of natural resources contribute to Ghana's environmental problems of rising carbon emission and energy consumption. However, international trade is found to reduce carbon emission. The implications from the results are discussed and the paper recommends among other things the need to strictly enforce laws regulating extractive activities in the country to ensure safe environment; and also to raise tariff and non-tariff barriers on products that do not promote friendly environment and vice versa.

Key words: CO_2 emission; energy consumption; Ghana; STIRPAT model; mining; natural resources

1. Introduction

Climate change is one of the topical issues that have 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 green house gases of which carbon dioxide (CO_2) is the chief (Intergovernmental Panel on Climate Change, 2001). The global emission of carbon dioxide has increased consistently over the years from 3,112,685.279 metric tons per capita in 1960 to 8,874,290.347 metric tons per capita in 1980 and over 12 million metric tons per capita by 2014 (World Development Indicators 2017). To address the issue of climate change, world leaders have devoted themselves to reduce CO_2 emission so as to help keep global temperature rise below the level of 2°C (Charfeddine et al., 2018). Policy makers, environmentalists and researchers have therefore committed themselves to identifying 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), developing countries (Asumadu-Sarkodie and Owusu 2016a; Charfeddine et al., 2018; Aboagye 2017a; Aboagye and Kwakwa 2014; Kwakwa and Adu 2016) and least developing countries (Asumadu-Sarkodie and Owusu 2016b; Ozturk and Al-Mulali 2016). Such studies have revealed a number of factors including energy consumption, population, trade and economic growth play significant role in determining the level of carbon 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 time period, the country and the methods employed in the previous studies and this could seriously affect policy and practical implications. Then again, previous studies have not considered or estimated the possible effect of natural resource extraction on environmental degradation. Natural resources extraction can contribute to environmental degradation through the high energy consumption required for extraction and the indiscriminate disposal of waste chemicals in to water, land and air. Thus, the aim of this study is to examine the environmental degradation 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¢783 million, GH¢ 2756 million and GH¢ 2076 million to Ghana's gross domestic product (Ministry of Lands and Natural Resources 2016). In addition, the mining sector alone is said to directly employ over 14,000 people (Kim et al., 2013) while supporting about111,000 jobs (Ghana Chamber of Mines and International Council of Mining and Metals 2015). Although the extractions of natural resources dates back to the 7^{th} and 8^{th} 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 (see 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.

Owing to the effect energy consumption has on climate change via CO_2 emission (Asumadu-Sarkodie and Owusu, 2016a; Asumadu-Sarkodie and Owusu, 2016b) it has become necessary to identify the determinants of energy consumption in order to help reduce CO_2 emission (Destek 2018). 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 emission effect and energy consumption effect of such extractive activities to help 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 the land, water bodies and air they do not employ any econometric tool to estimate the environmental degrading effect of such extractive activities as this study does. Second, previous studies that have explored the drivers of CO_2 emission do not account for natural resources utilization as it is done in this paper. Thirdly, the paper also argues and includes natural resources extraction in estimating the drivers of energy consumption. This will help offer further guidelines to policy makers in designing appropriate policies to tackle the energy problem that has bedeviled the country (see Adom and Bekoe 2012; Kwakwa 2018 for some facts on Ghana's energy demand and supply situation)

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

2. Literature Review

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 rates would put pressure on the environment in order to meet societal needs- 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 since there would be an increase in the consumption level of the economy; there would be stress on natural resources; and an increase demand for electrical and other high energy consuming machines. A high level of affluence is also associated with 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 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. Since its advancement, the STIRPAT model has been employed by many researches including Uddin et al., (2016), Hassan (2016), Li and Lin (2015) and Shahbaz et al., (2015a) to investigate the possible factors of carbon emission for countries. Others including Wang and Han (2016), Shahbaz et al., (2015b), Inglesi-Lotz and Morales (2017), Salim and Shafiei (2014) and Ma et al., (2017) have also employed the STIRPAT model to estimate the drivers of energy consumption. The results from all these studies have not been uniform. For instance, Li and Lin (2015) obtain a positive effect from population, income, urbanization, industrialization and energy intensity on carbon emission. For the economy of Bangladesh, Hassan (2016) finds that the emission effects of income, urbanization and technology are positive. Shahbaz et al., (2015) observe a long run positive effect of income, energy and trade openness on carbon emission. In their study, Wang et al. (2011) find 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 indicates 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) reports that affluence, urbanization and share of electricity increase CO_2 emission. The paper relies on time-series cross-section data spanning 1971-2007. For the Chinese economy, Sheng and Guo (2016) in their study examine effects of population, affluence, technology, and urbanization on carbon emission for thirty provinces in China between 1995 and 2011. In the long-run, the authors find an inverted U-shaped relationship between environmental regulation and carbon emission; a positive effect from industrial structure, urbanization and income on carbon emission; and a negative effect of population on carbon emission. Behera and Vishnu (2011) study the CO_2 emission effect of population, urban population, percentage of population between the age group of 15-60, per capita income, the service sector and the industrial sector for India and reports that with the exception of the population between the age group of 15-60 which has insignificant effect, the other variables exert positive effect on CO_2 emission for India. In his study Sadorsky (2014) found that urbanization, income and energy have significant effect on CO_2 emissions for a panel of emerging economies.

For sub-Saharan African countries, Amuakwa-Mensah and Adom (2017) employ 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 concludes that income, trade openness, and institutional quality reduce carbon emission while urbanization increases it. Other studies on Ghana and elsewhere that did not apply the STIRPAT model including Aboagye (2017), Kwakwa et al., (2014), Twerefou, *et.al.* (2016),Salahuddin et al., (2018) and Ozturk and Al-Mulali (2015) also note the significant effect of income, urbanization, industrialization and trade openness among others on carbon emission.

With regards to energy consumption studies that employed the STIRPAT model, such as Wang and Han (2016) find that research and development, income, investment in ICT and population reduce energy intensity in China. Inglesi-Lotz and Morales (2017) also report of a non linear relationship between education and energy consumption, and positive effects of population, industrial share and income on energy consumption. Shahbaz and Ozturk (2017) also record that income, technology and transportation increase energy consumption for Pakistan. Also, Shahbaz et al., (2015b) obtain a significant effect of urbanization, affluence, capital stock and trade openness on energy consumption.

Zongjie et al. (2016) also extend the STIRPAT model to examine energy consumption in a hotel. They report that occupancy rate, unit area of revenue, and unit revenue of energy consumption can positively increase in energy consumption of the hotel, but temperature can decrease energy consumption of the hotel. Cai et al, (2012) also employ the STIRPAT model to examine the driving factors of building energy consumption in China. Their ridge regression estimation results show that among other things that the household consumption increases energy consumption; population has a small impact on energy consumption; but the distribution of urban and rural population factors (urbanization rate) have greater influence than the total population factor. Ma et al., (2017) also report in their study 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 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) reveal 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. The conclusion from the above review is that although much is talked about carbon emission and energy consumption in the literature, there is little to no studies conducted that employs 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 STIRPAT model. As indicated at the section two, 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:

$$I_t = CP_t^{\beta_1} A_t^{\beta_2} T^{\beta_3} e_t^{\varepsilon_i} \qquad (1)$$

Where C is constant term, I is environmental impact, P is population, A is affluence, T represents technology, βs are the parameters to be estimated, e raised to epsilon is the stochastic term and t represents the time 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 represent 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. 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 to yield equation 2 below:

$$I_t = CP_t^{\beta_1} A_t^{\beta_2} T^{\beta_3} N_t^{\beta_4} e_t^{\varepsilon_i} \qquad (2)$$

We take the natural log of each variable in Equation (2) to get:

$$\ln I_t = c + \beta_1 \ln P_t + \beta_2 \ln A_i + \beta_5 \ln T_t + \beta_4 \ln N_t + \varepsilon_t \qquad (3)$$

Where ln is natural logarithm operator and c = lnC

3.2 Estimation Strategy

In order 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 tests respectively developed by Dickey and Fuller (1979) and Phillips and Perron (1988) for the stationarity test are employed. 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 Engle-Granger and the Phillips-Ouliaris Tests. Finally, we estimate the long run multipliers of energy consumption and CO_2 emission from equation (3) using the Phillips and Hansen (1990) Fully Modified OLS (FMOLS) The choice of this estimator is based on the fact that it able to correct for simultaneity bias and correlation among variables rendering it a more robust long run estimator than the popular ARDL cointegration technique. The Fully Modified OLS estimator is given as in the equation below:

$$\Phi_{FME} = \left(\sum_{t=1}^{T} Z_t Z_t^{'} \right)^{-1} \left(\sum_{t=1}^{T} Z_t y_t^{+} - T\hat{J}^{+} \right) \qquad (4)$$

where $y_t^{+} = y_t - \hat{\lambda}_{ox}\hat{\lambda}_{xx}^{-1}\Delta x_t$ is the correction term for endogeneity, and $\hat{\lambda}_{ox}$ and $\hat{\lambda}_{xx}$ are the kernel estimates of the long-run covariances, $\hat{J} = \hat{\Delta}_{ox} - \ddot{\lambda}_{ox}\hat{\lambda}^{-1}{}_{xx}\hat{\Delta}_{xx}$ is the correction term for serial correlation, and $\hat{\Delta}_{ox}$ and $\hat{\Delta}_{xx}$ are the kernel estimates of the one-sided long-run covariances. To ensure robustness of the results equation 3 is also estimated using the Canonical Cointegrating Regression (CCR) estimator.

3.3 Data description and source

This study used annual time series data covering 1971-2013 sourced from WDI (2017) data base. 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, the per capita carbon dioxide emission (CO2), and Energy use (kg of oil equivalent per capita) (ENER). Also, population is represented by urban population (% of total) (URB), affluence is represented by adjusted GDP per capita (YPC), trade is represented by the sum of import and export as a share of GDP, and natural resource extraction (NAR) is measured by total natural resources rents (% of GDP).

Table 1 shows the descriptive statistics of the annual time series data covering the period 1971 to 2013 where for instance, the mean energy consumption is 346.42 kg, while the average carbon dioxide emission per capita is 0.32. However, the mean of natural resources rents as a percentage of GDP is 1.69. Trade as a share of GDP has a mean of 55.61, while the average adjusted GDP per capita is $32,279.90. Urban population as a share of total population has a mean value of 38.95%.

Table 1: Descriptive statistics

	ENER	CO2	TO	UR	YPC	NAR
Mean	346.4190	0.315984	55.61088	38.94588	32279.90	1.694797
Median	359.8670	0.303202	45.99360	37.90500	299.8784	0.862670
Maximum	417.7570	0.558786	116.0484	52.73500	332212.9	8.417575
Minimum	271.2763	0.209693	6.320343	29.17400	5.676208	0.038760
Std. Dev.	38.24621	0.073067	29.99912	7.694337	77946.81	2.115622
Observations	43	43	43	43	43	43

4. Empirical results

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

4.1 Unit root and cointegration analysis

The stationarity of each variable was checked using the PP and ADF tests, and the results presented in Table 2 indicate that at levels, the PP test accepts the presence of unit root for all the variables except lnYPC while the ADF test accepts the presence of unit root for all the variables except lnYPC and lnURB. However, at first difference all the other variables become stationary. This implies that lnYPC and lnURB are integrated of order zero, I(0) and all the other variables are integrated of order one, I(1). Table 3 presents the results of the cointegration tests based on the Engel-Granger and Phillips-Ouliaris tests.

Both tests for the CO_2 model show that the null hypothesis of no cointegration is rejected, which suggests the existence of long-run relationship among the variables lnCO_2, lnYPC, lnURB, lnTO and lnNAR. Regarding the energy, the results for the cointegration test among the series is mixed. The Engel-Granger cointegration test rejects the null hypothesis of no cointegration, while the Phillips-Ouliaris tests accept it. Owing to this mixed outcome, the Hansen cointegration test was employed to ascertain the cointegration outcome and the results confirmed cointegration exist between energy consumption, income, urbanization, trade and natural resources extraction activities. On this ground it is fair to conclude the existence of long-run relationship among lnENER, lnYPC, lnURB, lnTO and lnNAR.

Table 2: Unit root test results

	PP		ADF	
Variables	Intercept	Intercept and trend	Intercept	Intercept and trend
		At levels		
lnCO_2	-0.3982	-2.8488	-0.0296	-3.0434
lnYPC	-3.3234**	-0.2705	-3.8925***	-0.0710
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
		At first difference		
lnCO_2	-10.8348***	-24.8674***	-9.2197***	-9.3769***
lnYPC		-5.6309***		-5.6509***
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***

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

Table 3: Cointegration

Series	Engel-Granger tau-statistic	Engel-Granger z-statistic	Phillips-Ouliaris tau-statistic	Phillips-Ouliaris z-stattistic
$lnCO_2$ | lnYPC, lnURB, lnTO & lnNAR	-6.3188***	-41.9411***	-6.4140***	-38.6188***
lnENER | lnYPC, lnURB, lnTO & lnNAR	-3.5048	-26.7081*	-3.1827	-16.4126

*** and * denotes 1%, and 10% level of significance respectively.

4.2 Estimation of long-run relationship – FMOLS and CCR approaches

The results of both FMOLS and CCR estimates for the CO_2 model show that income, natural resource extraction, urbanization and trade openness significantly affect carbon dioxide emissions in Ghana while income, natural resource extraction and urbanization affect energy consumption (Table 4). The findings are discussed below:

Table 4: Long run estimates for carbon emission and energy consumption

Variable	FMOLS: CO2	CCR: CO2	FMOLS: energy	CCR: energy
lnYPC	0.1294***	0.1317***	0.07438***	0.0772**
	(6.6636)	(6.3159)	(2.5803)	(2.4730)
lnNAR	0.4635***	0.5109***	0.9249***	0.9571***
	(3.5308)	(3.4241)	(4.7505)	(4.2668)
lnURB	3.7550***	3.8207***	1.7385**	1.8240**
	(7.6201)	(7.0618)	(2.3796)	(2.2444)
lnTO	-0.1061***	-0.1080***	-0.02889	-0.0352
	(-3.4994)	(-2.9933)	(-0.6407)	(-0.6551)
Constant	-17.1851***	-17.6362***	-4.6942	-5.1347
	(-7.4384)	(-6.9310)	(-1.3703)	(-1.3436)
Adj R-squared	0.73	0.72	0.65	0.64

*** and ** denotes 1%, and 5% level of significance respectively.

4.2.1 Environmental effect of income

From Table 4, income is seen to exert positive effect on energy consumption and carbon dioxide emissions. A 1 percent increase in adjusted per-capita GDP increases carbon dioxide emission by 0.13%. This suggests that increase in income leads to environmental degradation. A high level of affluence is associated with increase in production and consumption of goods (Shahbaz *et al.* 2015a), which may lead to over exploitation of natural resources, and an increase generation of wastes and pollution that may degrade the environment. This result is similar to that of Wang *et al.* (2011) and Martínez-Zarzoso (2008). Concerning energy, according to the results, a 1% increase in adjusted per-capita GDP increases energy consumption between 0.07-0.08%. This is reasonable because as the economy grows, the demand for high energy consuming products also increases which increase the consumption of energy.

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 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 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 increasing carbon emissions. This finding is consistent with that of Shahbaz and Ozturk (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.

4.2.2 Environmental effect of natural resource extraction

The elasticity of CO_2 with respect to natural resource extraction is positive, suggesting that a 1 percent increase in natural resource extraction increases carbon dioxide emissions between 0.46-0.51%. It is possible to attribute the environmental degrading effect of natural resource extraction in Ghana to the mining activities (both legal and illegal mining) and increasingly oil exploration in the country. As argued by Mensah *et al.* (2015), the operations of illegal mining activities in Ghana do not meet the minimum environmental standards and as such pollute the environment. Further, the extensive usage and disposal of mercury and arsenic associated with mining into the environment pollute water bodies, soil and vegetation. For instance, Kumah (2006) has revealed that between 1994 and 2001, five major cyanide spillages and leakages by mining companies led to the contamination of major Western Region rivers such as Anikoko, Angonabe, Bodwire and Assaman rivers. The recent spate of illegal mining activities has had similar effects on the rivers Pra, Ankobra and Birim and other smaller rivers in the mining communities. The consequential effect of this as outlined by Mensah et al., (2015) has been that aquatic organisms have been lost; people have been displaced; livelihood has been depleted and loss of drinking water for communities. In the Prestea mining communities, Mensah et al., (2015: 87) have noted that mining has caused many portions of the land to lose its vegetation cover leading to "massive gullies, excessive run-off, heavy erosion, reduced soil infiltration, reduction in groundwater recharge and consequent loss of land productivity." The end result is that the quality of the land for farming is also affected negatively.

Owing to the devastating nature mining has left some mining communities in the country, there has been protest by some group 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 c. 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 is to embark upon a 95km 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 reported that the burning of natural gas to dispose of gas produces nitrogen dioxides, carbon dioxide and photochemical oxidants which degrade the environment. In addition, the increasingly oil exploration consume high level of energy which emits carbon dioxide and this degrade the environment. 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 2016:6) have been found to pollute the environment. They also reveal that construction work, drilling, ships traffic and seismic surveys associated with the offshore oil and gas industry lead to noise pollution which also affect stability of the ecosystem of the sea and on the habitat.

With regards to the energy model, the estimated coefficient also shows that natural resource extraction increases energy consumption. This result is expected because the continuous extraction of natural resources in the country depends largely on energy without which equipments for such extractive activities would be difficult to function. Thus, as extraction activities increase, energy consumption also increases in Ghana. The coefficient implies that an increase in natural resource extraction activities by 1% will increase energy consumption by 0.9%. Although its effect is inelastic it is quite larger and even it is found to exert the second most significant impact on the country's energy consumption after urbanization. It is an indication for authorities to therefore pay attention to natural resources extractive activities when drawing plans to deal with the countries energy security issues.

4.2.3 Environmental effect of urbanization

The results also reveal that a 1 percent increase in urbanization rate increases carbon dioxide emissions between 3.76-3.82% in the long term. This implies that urbanization has environmental degradation effect in Ghana. In 2010, Ghana for the first time ever saw an estimated 51% 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 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. In addition, the current uncontrolled urbanization in the country has led to increase in waste generation which has outpaced the capacity of local government to manage it sustainably; such that Ghana is ranked among the dirtiest place in Africa (Blacksmith, 2013). The result is consistent with those of Kwakwa and Adu (2016), Adams *et al.* (2016), and Amuakwa-Mensah and Adom (2017).

Urbanization is found to have statistically significant positive effect on energy consumption. A 1% increase in urbanization rate increases energy consumption between 1.74-1.82% in the long-run. This is reasonable because rapid urbanization increases the consumption of goods and service, with an increase in energy used for their production. Furthermore the construction, operation and maintenance of urban infrastructure such as the transport system increase the consumption of energy. This result is in tandem with that of Shahbaz *et al.* (2015).

4.2.4 Environmental effect of trade openness

From the results, trade openness is found to reduce CO_2 emissions in the long-run. 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). Others also argue that trade 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. The scale effect of trade deteriorates the environment as it helps to expand activities of production and consumption. However, trade may also through its composition effect help transform the economy from an agricultural based to industrial and then finally to service based where pollution is relatively low. In addition, the technique effect of improves environmental quality by enabling countries import low pollution production technique (Erickson *et al.,* 2013).This suggests that the environmental improving effects of trade outpaces the negative effects of trade in the case of Ghana. The result is in consonance with that of Adams *et al.* (2016) and Wang *et al.* (2011).

With regards to energy, trade is found to have a negative coefficient although it is not statistically significant. Ghani (2012) reported similar outcome in his study on 52 developed and developing economies. In the case of Ghana, it contradicts Kwakwa and Aboagye (2014) who report of a long-run positive effect of trade openness on energy consumption, and Adom and Kwakwa (2014) who report of a long-run negative effect of trade on energy intensity. The implication is that although researchers have given attention to the relationship between trade and energy (Kwakwa 2017), the fewer studies that exist in Ghana are far from reaching consensus.

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 carbon dioxide emission has done little to econometrically estimate the impact of natural resource extraction. Owing to the recent public outcry of the effect of mining 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 carbon dioxide emission and energy consumption in the country. The FMOLS and CCR methods were used to estimate the long-run determinants of energy consumption and CO_2 emission. The results reveal that income, urbanization, and natural resource extraction activities contribute to Ghana's environmental problems of rising carbon emission and energy consumption, while international trade is found to reduce carbon emission.

The findings from this study have policy implications. First, income and urbanization were found to increase carbon emissions and energy consumption. Thus, policy makers should promote the development and usage of low-carbon technology and encourage efficient use of energy to address energy security and urban development. Since natural resource extraction activities degrade the environment, the paper recommends the strict enforcement of laws regulating mining and oil production activities in the country to ensure 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 also necessary to create the necessary environmental awareness in mining communities and forest areas where illegal activities are common. Furthermore the cumbersome registration process small scale miners need to go through to acquire license needs to be relooked at to make it less difficult and frustrating. The effect will be that many illegal miners will secure the right for mining and that may reduce the environmental effect. In addition, policy makers need to pay attention to natural resources extractive activities in dealing with the countries energy security issues. It is recommended that government facilitates to enable natural resources extractive firms to acquire energy efficient equipments 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 friendly environment whiles reducing tariffs on products that promote quality environment.

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