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A Study on the Evidence of the Environmental Kuznets Curve Hypothesis in Ghana

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Approved by

Professor Jaywon Lee

[1] Declaration of Ethical Conduct in Research: I, as a graduate student of KAIST, hereby declare that I have not committed any acts that may damage the credibility of my research. These include, but not limited to: falsification, papers written by someone else, distortion of research findings or plagiarism. I affirm that my research paper contains honest conclusions based in my own careful research under the guidance of my academic advisor.

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ABSTRACT

The study is an effort to fill the gap in the environment-growth literature with a comprehensive country study on Ghana. The study investigates the relationship between CO_2 emissions, economic growth, energy consumption and trade openness in Ghana using time series data from 1980-2011. Hendry Error Correction Model (ECM) and Pairwise Granger causality test are used for the empirical analysis. The results suggest that there exists a long-run relationship among the variables and the Environmental Kuznets Curve (EKC) hypothesis is supported in the long-run. The significant existence of EKC shows the country's effort to reduce CO_2 emissions and confirms modest achievements in controlling environmental degradation in Ghana. Furthermore, we find a uni-directional causality from economic growth to CO_2 emissions, energy consumption and trade openness; energy consumption to CO_2 and CO_2 to trade openness. Energy consumption decreases CO_2 emissions both in the short and long run. Trade openness is positive but insignificant both in the short and long run. In addition, a disequilibrium in the CO_2 emissions and growth relationship in the short run converges to long run equilibrium at a speed of 122 percent yearly.

Keywords: Carbon dioxide Emissions, Environmental Kuznets Curve, Carbon sink, Greenhouse Gases

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LIST OF ABBREVIATIONS

ADF	Augmented Dickey-Fuller
CH_4	Methane
CO_2	Carbon dioxide
EPA	Environmental Protection Agency
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GDP^2	Gross Domestic Product squared
GHG	Greenhouse Gas
GSS	Ghana Statistical Service
HES	High Emission Scenario
IBRD	International Bank for Reconstruction and Development
LES	Low Emission Scenario
LMIC	Lower Middle Income Country
LPG	Liquefied Petroleum Gas
$MtCO_2e$	Metric tons of CO_2 equivalent
NAFTA	North America Free Trade Area
NEEDS	National Environmental, Economic and Development Study
NDPC	National Development Planning Commission
N_2O	Nitrous Oxide
OECD	Organisation for Economic Cooperation and Development
OLS	Ordinary Least Square
PP	Phillips-Perron
SO_2	Sulfur dioxide
SSA	Sub-Sahara Africa
WDI	World Development Indicators

DEDICATION

To my wife, Letitia and daughter, Kharis

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1 INTRODUCTION

For the sake of human development, the real value of natural resources has often been overlooked, so that they have been subject to over-consumption in both production and consumption activities. Over the course of the 20th century, the situation has worsened to an extreme point along with the unprecedentedly quick pace of economic growth. Observing how fast the exhaustion of the non-renewable resources, how alarmingly irreversible the dangers linked to climate changes, many scholars have expressed their worries that such a remarkable economic “prosperity” may not be sustainable in the future. Supposing the future economic growth model remains unchanged and the population/industrial capital keeps growing exponentially, as claimed in “The Limit to Growth” (Meadows et al. 1972), “*The Club of Rome*” report, then the limited supply of both food and non-renewable resources will lead to the collapse of our production system and to the halt of our economic growth before 2100 (Cole, 2000).

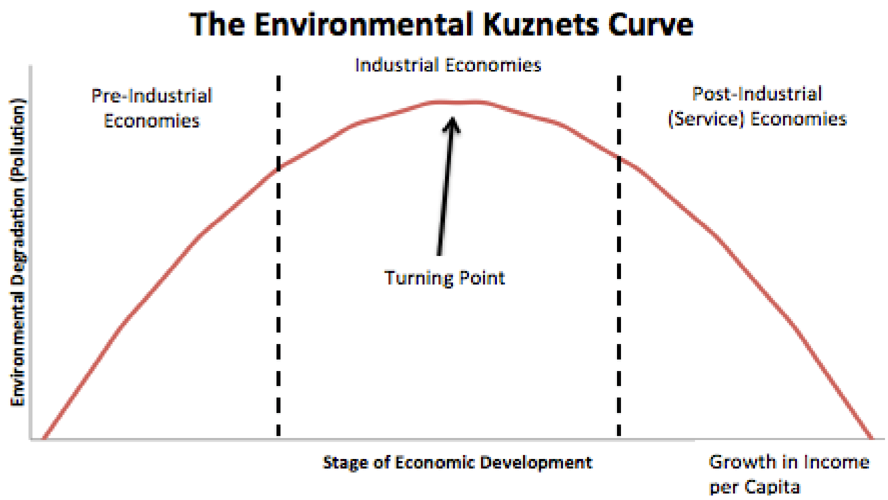
The advent of the Environmental Kuznets Curve hypothesis is closely related to both the fear linked to the “limits of growth” and to the concept of “sustainable development”. Originally based on empirical findings, the famous inverted-U curve predicted by this hypothesis concerning spectrum, Beckerman (1992) argues that the easiest way to obtain environmental improvement is to carry on with the original economic growth path and endure the transient environmental deterioration. Claiming both the demand and supply capacity for a better environment increase along with the income, he concludes that, “the strongest correlation between the incomes and the extent to which environmental protection measures are adopted demonstrates that in the long run, the surest way to improve your environment is to become rich”. In his very controversial book “*The Sceptical Environmentalist*”, Lomborg (2001) also describes our future as a “beautiful world”. After drawing both environmentally and economically-oriented comparisons regarding various aspects of the world over the last century, he concludes that this world “is basically headed in the right direction and that we can help to steer this development process by insisting on reasonable prioritisation (the economic growth)”. Barlett (1994) goes even further in his claims about environment-growth nexus. For him, environmental regulation, as a policy tool reducing economic growth, would actually cause environmental quality to decrease.

Does economic growth increase or decrease pollution levels in the environment? Recently, economists have been trying to solve this question by analysing trends and patterns of pollution across countries and over time. One hypothesis is that a country's pollution concentrations rise with economic growth and industrialization up to a certain point, after which the country uses its increasing wealth and development to reduce pollution concentrations again. If true, plotting pollution concentrations against income per capita will yield an inverted U curve – or what has been called the EKC (Jbara, 2007) as depicted in Figure 1.

The multiple crises – environmental crisis (caused by the ozone layer depletion) and financial crisis- experienced in recent times have shook the very foundations of most economic systems in the world and has called for radical moves by governments of different economies in Asia, South America, and Africa to deal with these crises. In spite of these historical antecedents, the continent of Africa has been noted or spotted by many to be the 'milky breast' for the rest of the world in generations to come. This is so because the continent of Africa is still seen to be green with a lot of unexploited opportunities. However, as countries in Africa seek to grow, caution must be taken in the likely consequences this growth would have on the environment, climate and human adaptation. Thus, as African countries strive to expand their economies, it must be complemented with some emission control measures.

In any economy the levels of carbon dioxide emissions are closely related to social, economic and industrial factors. In order to develop any effective emission control measure, it is of outmost importance to determine the interplay between the socioeconomic activities or phenomenon that lead to anthropogenic emission of carbon dioxide. This will help bring out the forcing relationship that socio-economic factors have on carbon dioxide emissions (Adom, et al., 2012).

Figure 1.1: Environmental Kuznets Curve



Source: Wikipedia

The EKC hypoyhesis posits an inverted-U relationship between pollution and economic development as shown in figure 1. Kuznets' name was apparently attached to the curve by Grossman and Krueger (1993), who noted its resemblance to Kuznets' inverted-U relationship between income inequality and development. In the first stage of industrialization, pollution in the EKC theory grows rapidly because people are more interested in jobs and income than clean air and water, communities are too poor to pay for abatement, and environmental regulation is correspondingly weak. The balance shifts as income rises – leading industrial sectors become cleaner, people value the environment more highly, and regulatory institutions become more effective. Along the curve, pollution levels off in the middle-income range and then falls toward pre-industrial levels in wealthy societies (Dasgupta, et. al., 2002).

The EKC model has elicited conflicting reactions from researchers and policymakers. Applied econometricians have generally accepted the basic tenets of the model and focused on measuring its parameters. Their regressions, typically fitted to cross-sectional observations across countries or regions, suggest that air and water pollution increase with development until per capita income reaches a range of $5000 to $8000. When income rises beyond that level, pollution starts to decline, as shown in the "conventional EKC" line in Figure 1. In developing countries, some policymakers have interpreted such results as conveying a message about priorities: Grow first, then clean up (Dasgupta, et. al., 2002).

The reasoning behind the EKC hypothesis has been put succinctly as follows: At low levels of development both the quantity and intensity of environmental degradation is limited to the impacts of subsistence economic activity on the resource base and to limited quantities of biodegradable wastes. As economic development accelerates with the intensification of agriculture and other resource extraction and the take off of industrialisation, the rates of resource depletion begin to exceed the rates of resource regeneration, and waste generation increases in quantity and toxicity.

At higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in levelling off and gradual decline of environmental degradation (Panayotou, 1993).

This argument leads to a hypothesized relationship between environmental degradation and income per capita which takes the form of an inverted U-shape. Such a relationship is sometimes called an “environmental Kuznets curve”, EKC, after Kuznets (1955) who hypothesized an inverted U for the relationship between a measure of inequality in the distribution of income and the level of income. If the EKC hypothesis held generally, it could imply that instead of being a threat to the environment as argued in, for example, The Limits to Growth (Meadows et al., 1972), economic growth is the means to environmental improvement.

Naoto (2006) revealed that between 1990 and 2000 Africa has the highest rate of deforestation of about 0.8 percent and this was substantially greater than the world average of 0.2 percent (FAO, 2005). Furthermore, Diarrassouba and Boubacar (2009) revealed that with the exception of 1999, the period between 1990 and 2004 witnessed a massive increase of the rate in deforestation in Africa and Sub Saharan Africa as well. Ghana covers over 23 million hectares of land area and of this, nearly 13,628,179ha under agricultural use. Ghana’s total forest cover is now less than 1.6 million hectares with an annual deforestation rate projected to be 2 percent (EPA Ghana).

Yet, the impact of economic growth, trade openness and energy consumption on the environment in Ghana is not well established in the literature. This could explain the non-existence of stringent environmental policies in Ghana (Copeland and Taylor, 2003). From policy perspective, knowing the direction in which economic growth and growth-related policies such as greater openness to trade, energy consumption among others tend to have on the environment is very essential.

This study seeks to establish the relationship between environmental degradation and economic growth by validating whether the EKC hypothesis exists in Ghana. The study will also attempt to determine the income level beyond which environmental degradation will decrease with rising income; and whether trade openness affect environmental quality in Ghana.

This study has been motivated by Omojolaibi (2010) who used panel data to analyse the relationship between environmental quality and economic growth in Ghana, Nigeria and Sierra Leone from 1970-2006. The results based on the Fixed Effect model indicated that individual country effect does not conform to the EKC hypothesis though, coefficients have the expected signs with GDP positively related to CO_2, while GDP^2 has a negative correlation with CO_2. Based on these findings this study attempts to investigate if the hypothesis can be validated for Ghana by using single country data. Secondly, not much empirical studies have been done on Ghana to investigate the relationship between the environment and economic growth. As Ghana has transited into a Lower-Middle Income Country (LMIC) with high energy demand and a vibrant Oil and Gas sector, it is very crucial for this relationship to be investigated so that energy and environmental policy decisions will be empirically supported. Hence, the findings from this study will contribute to the huge literature gap that exists in that research area but most importantly the recommendations will help in formulating policies.

The study is an effort to fill the gap in the environment-energy-income literature because there is lack of comprehensive studies for Ghana. Single country studies help policy making authorities in making comprehensive policies to control environmental degradation. This study contributes to the literature with a case study of Ghana using time series data for the period of 1980–2011.

The study is organised in five chapters. Chapter one provides the introduction to the study, chapter two reviews both the theoretical and empirical literature, chapter three looks at environmental degradation and economic growth in Ghana, chapter four looks at the data, methodology, estimation techniques and the analysis of results. Chapter five focuses on conclusion and policy recommendations.

2 LITERATURE REVIEW

2.1 Theoretical Review

2.1.1 Environment and International Trade

Proponents of free trade argue that increased trade will lead to increased world income. However, it is argued that intensive trade has environmental consequences that may outweigh the gains from income. It is also argued that free trade worsens the already existing environmental problems of economic activity. This takes the form of depleted non-renewable resources or harmful emissions. Besides, trade ignores the social costs of environmental degradation; and it is for this reason governments regulate industry and impose trade restrictions. Comparative advantage is the hallmark of free trade but it is argued that seeking this advantage can lead to further environmental degradation (PanLong Tsai, 1999). A number of hypotheses have been developed to explain the trade-environment nexus. These are: the Pollution Haven Hypothesis, the Factor Endowment Hypothesis, the EKC and the Porter Hypothesis.

a) Pollution Haven Hypothesis

The "Pollution Haven Hypothesis" claims that countries with less stringent environmental regulations will attract pollution-intensive industries when they adopt trade liberalization policies. This hypothesis postulates that costs of production will be less in those countries with more lenient environmental standards, and as a consequence attract potential producers of pollution-intensive goods should such countries open up to free trade. The pollution haven hypothesis further asserts that governments in most developing nations are hesitant to place strict environmental standards on their firms in order to boost the competiveness of local firms in the global market. According to the pollution haven hypothesis, most developing countries experience deterioration in environmental quality when they open up to trade mainly as a result of ineffective environmental regulations (Busse, 2004).

b) Factor Endowment Hypothesis

The Factor Endowment Hypothesis contends that with trade liberalization, individual countries will tend to produce and export goods for which they have large resource endowments. Thus, countries that have enormous endowments of natural and material resources are very likely to specialize in resource-intensive industries and thus increase the extraction of natural resources when they open up to trade. This hypothesis further argues that in countries where property rights on common property resources are not well defined or where environmental standards are not properly enforced, trade openness is likely to result in more resource degradation and deforestation. Even more seriously, lack of property rights on resources may lead countries to specialize in the production and export of natural resource–intensive activities and hence further-up environmental degradation even if they are not richly endowed with natural resources. The central point of the factor endowment hypothesis is that, the institutional and regulatory failures in a nation may lead to false comparative advantages, in which case trade may reduce rather than raise income as is normally assumed under the EKC Hypothesis, and thereby result in further deterioration in environmental quality (Lopez and Islam, 2007).

c) Porter's Hypothesis

A recent hypothesis, called the Porter Hypothesis, proposes that in an era of free trade, environmental regulations or trade standards are beneficial to both the environment and competitiveness. The hypothesis opposes the standard view of free trade and the environment as a trade-off. The hypothesis claims that countries that "go green," will have a competitive advantage in trade for two reasons: the first is that regulation or trade standards will compel local firms to become aware of alternative methods of production that may be more efficient. The second is that because of the tendency for regulation to become more restrictive, firms that have already adjusted to the changes will have an initial comparative advantage against firms adjusting for the first time. Critics of the argument counter that; rational firms will not require environmental regulations to prompt research into more efficient production. Their other critique is that in the event that regulations are not tightened, the firm that adopted more environmentally friendly standards will be at a competitive disadvantage with trade liberalization (Hanley et al, 2001).

2.1.2 Environmental and Economic Growth

The EKC concept emerged in the early 1990s with Grossman and Krueger's (1991) pathbreaking study of the potential impacts of NAFTA and Shafik and Bandyopadhyay's (1992) background study for the 1992 World Development Report. However, the idea that economic growth is necessary in order for environmental quality to be maintained or improved is an essential part of the sustainable development argument promulgated by the World Commission on Environment and Development (1987) in *Our Common Future*. The EKC theme was popularized by the World Bank's World Development Report 1992 (IBRD, 1992), which argued that: "The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investments" (IBRD, 1992) and that "As incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment". Others researchers have expounded this position even more forcefully with Beckerman (1992) claiming that "there is clear evidence that, although economic growth usually leads to environmental degradation in the early stages of the process, in the end the best – and probably the only – way to attain a decent environment in most countries is to become rich."

a) The Scale Effect

If there were no change in the structure or technology of the economy, pure growth in the scale of the economy would result in a proportional growth in pollution and other environmental impacts. This is called the scale effect. The traditional view that economic development and environmental quality are conflicting goals reflects the scale effect alone. Proponents of the EKC hypothesis argue that “at higher levels of development, structural change towards information-intensive industries and services, coupled with increased environmental awareness, enforcement of environmental regulations, better technology and higher environmental expenditures, result in levelling off and gradual decline of environmental degradation.” (Panayotou, 1993,).

b) The Time Effect

The sensitivity of the EKC shape with respect to sample choice can first be observed concerning the time dimension. Harbaugh et. al. (2000) used exactly the same estimation function form and the same database as Grossman and Krueger (1991). Yet, when they extended the database by another ten years, they found that the estimated pollution-income relationship turned into an inverted-S shape. Thus, it appears essential to be cautious when projecting the future pollution-income trajectory from environment improvement data grounded in a given historical period: in time, some necessary and sufficient conditions resulting in the downward-bending trend may disappear.

2.1.3 Environment and Firm Competitiveness

Another closely related issue is the relationship between environmental regulation and competitiveness. The conventional wisdom suggests that the cost of environmental regulation slows productivity growth and impedes competitiveness in international markets. The opposite view, expressed by the so-called Porter hypothesis and supported by a series of case studies, where firms under strict environmental regulation prove to be very successful, suggests that tough environmental regulation in the form of economic incentives can trigger innovation that may eventually increase a firm’s competitiveness and may outweigh the short run private costs of this regulation (Porter and van der Linde, 1995). On the theoretical level the validity of this hypothesis has not been established without resorting to specific assumptions regarding X-efficiency, or strategic trade models (Simpson and Bradford, 1996). It has also been criticized for introducing a “free lunch” idea and potentially distracting attention from the cost-benefit analysis of environmental policy (Palmer, Oates and Portney, 1995). It has also been shown (Xepapadeas and de Zeeuw, 1999) that modernization of capital stock induced by a tougher environmental policy might not provide the full benefits assumed by the Porter hypothesis, but is expected to increase the productivity of the capital stock, along with a relatively less severe impact on profits and more emission reductions.

2.2 Empirical Review

The new (post-Brundtland) conventional wisdom that developing countries are "too poor to be green" (Martinez-Alier, 1995) is, itself, lacking in wisdom. In rapidly growing middle-income countries, however the scale effect, which increases pollution and other degradation, overwhelms the time effect. In wealthy countries, growth is slower, and pollution reduction efforts can overcome the scale effect. This is the origin of the apparent EKC effect. The econometric results are supported by recent evidence that, in fact, pollution problems are being addressed and remedied in developing economies (e.g., Dasgupta, et al., 2002).

2.2.1 The EKC shape and its sensitivity to the choice of country samples

The instability of the EKC shape is also observed when different country samples are included in the database. A telling example is Stern and Common (2001) vs. Selden and Song (1994). Using only the 22 OECD countries' data, Selden and Song (1994) found an EKC whose turning point ranged at about $8000-$10000. Stern and Common (2001) enlarged the database, including 73 countries in it and most of the new data in connection with developing countries. Their conclusion reveals that the "turning point (of the EKC) becomes quite higher when the data of developing countries are included or separately estimated". If their OECD sub-sample still yields an EKC turning point ($9181) that is similar to the one in Selden and Song (1994), the global and non-OECD countries samples actually reveal much higher turning points: $54199 10 (global) and $343689 (non-OECD). Hence, it seems that extrapolating the developed countries' environment-income experience to predict that of developing countries is not always relevant, all the more so since the latter seem to have a harder time improving their pollution-income trajectory.

2.2.2 The EKC shape and its sensitivity to Environmental Measurements

Another source of sensitivity is related to the environmental indicators' measurements. The "measures of the environmental degradation fall in two general categories: emission of the pollutants and environmental concentrations of pollutants" (Kaufman et al., 1998). These two measurements illustrate different aspects of the environmental degradation situation and neither of them can offer a comprehensive description. "Emission directly measures the amount of pollutants generated by economic activities during a period without regarding to the size of the area into which the pollutants are emitted". It is actually a flow measurement for the polluting capacity of economic activities. "The concentration measures the quality of pollutants per unit area without regarding to the activity that emitted them", it is more like a stock measurement describing the final result of the encounter between emission, abatement efforts and the self-purification capacities of nature. As concentration is a more direct environmental quality indicator and has more direct impact on productivity and public health, Selden and Song (1994) believe it should be easier to obtain an inverted-U curve for concentration than for emission indicators. The studies listed in Table 1 confirm this proposition, especially for the oldest studies in which the estimation methods or sample selections had not yet played a significant role in changing estimation results.

2.2.3 The EKC shape and its sensitivity to various econometrical strategies

In order to improve econometrical efficiency, more recent EKC studies have focused on estimation methods, working along four lines of research. In the first one, research is conducted to reveal the part played by country-specification in the environment-income relationship. It ranges from the very first simple cross-section OLS estimation that supposes the environment-income relationship is an internationally homogenous correlation (Panayotou, 1993 and Shafik, 1994), to the panel data estimator which includes group-specific effects into the estimation to capture the country-specific heights in EKC, and finally to the random coefficient panel data model which yields country-specific coefficients for income and income square terms (List and Gallet, 1999). It can be generally observed that improvements regarding estimation efficiency are counterbalanced by two negative effects: first, less coherence is observed between countries regarding the environment-income relationship; second, the one-form-fit-for-all EKC curve derived from international experience proves less efficient as a prediction tool.

The main goal of the second category of studies is to “demystify” the EKC hypothesis (Panayotou, 1997). It essentially investigates the underlying structural factors obscured by income growth, such as structural changes, population density, technological progress, institutional development, inequality, etc. As mentioned in the conclusion of these studies, including other factors into estimations does affect the simple environment-income correlation predicted by the EKC hypothesis, therefore, enhancing the instability in the form and turning point of the EKC (Cole 2004).

In the third group of studies, pollution indicator and income level are regarded as two time series originally sharing the same uniformly increasing trend: in this view, the decoupling between these two series is accounted for by the fact that technical progress in pollution 12 abatement activities supposedly dominates the economic scale enlargement leading to a pollution increase (De Bruyn et al., 1998). The last econometrical line of research focuses on the potential estimation bias related to the fact that the estimation function is predetermined as either a square or cubic shape. By simply comparing the estimation results obtained from different function shapes or using more rigorous statistical methods such as semi or non-parametrical models, these studies find the decision to include or not the polynomial income term largely affects the location of the EKC turning point (Bradford et al., 2000).

2.2.4 Other factors also affecting EKC shape

The sensitivity regarding the turning point of the EKC hypothesis can also be explained by the economic sources of pollution. In their study, Dinda et al. (2000) finds that the turning point of the EKC in residential areas proved much higher than in areas with intense commercial activity. The reason for this discrepancy is that in residential areas, the trade-off between the consumption-related utility increase and the pollution-related disutility that comes with consumption is more difficult. The EKC turning points may also be different when the interested pollution indicators reflect the average environment situation of a whole country and when they merely illustrate the situation in urban areas. Considering many EKC studies are based on the GEMS data collected in the cities of 30 countries all over the world, Selden and Song (1994) indicate that the turning points revealed by these studies might be lower than those revealed by the studies showing the national average environmental trends in connection with income growth because it is in urban areas that environment quality control activities are set up in the first place.

The recent studies that use more representative samples of the data find that there is a monotonic relation between carbon dioxide and income. Interestingly, Dijkgraaf and Vollebergh (1998) estimated a carbon EKC for a panel data set of organization for economic corporation and development (OECD) countries finding an inverted-U shape EKC in the sample, as a whole. Lopez (1994) uses a fairly general theoretical model to show that if producers pay the social marginal cost of pollution, then the relationship between emissions and income depends on the properties of technology, as well as preferences. If preferences are homothetic, so that percentage increases in income lead to identical percentage increases in what is consumed, then an increase in output will result in an increase in pollution. But if preferences are non-homothetic, so that the proportion of household spending on different items changes as income rises, then the response of pollution to growth will depend on the degree of relative risk-aversion and the elasticity of substitution in production between pollution and conventional input.

Shafik and Bandyopadhyay’s (1992) study was particularly influential as the results were used in the 1992 World Development Report (IBRD 1992). They estimated EKCs for ten different indicators using three different functional forms. Lack of clean water and lack of urban sanitation were found to decline uniformly with increasing income, and over time. Both deforestation regressions showed no relation between income and deforestation. River quality tended to worsen with increasing income. Local air pollutant concentrations, however, conformed to the EKC hypothesis with turning points between $3000 and $4000. Finally, both municipal waste and carbon emissions per capita increased unambiguously with rising income.

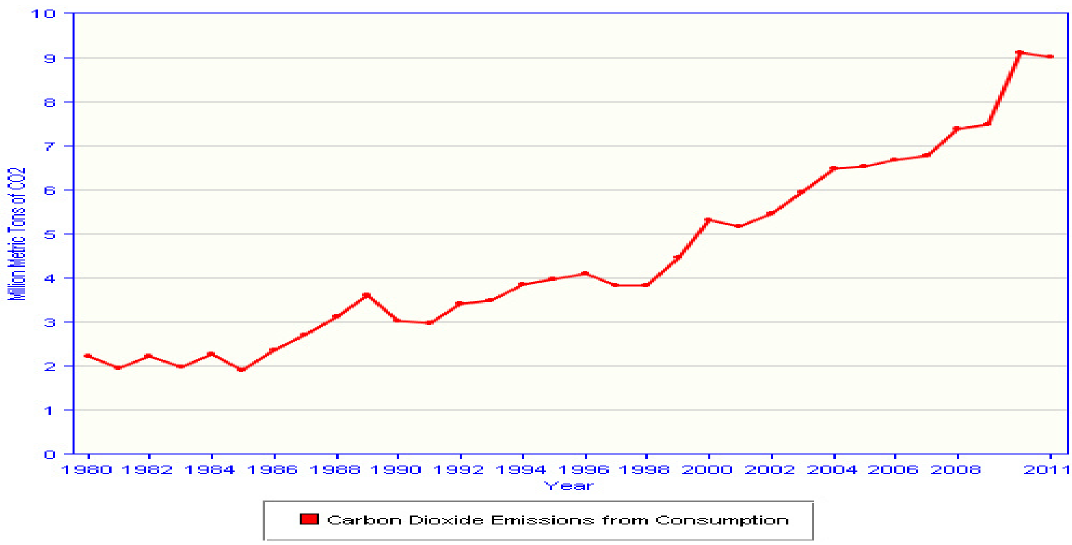
3 ENVIRONMENTAL DEGRADATION AND ECONOMIC GROWTH IN GHANA

3.1 Economic Growth and Environmental Quality in Ghana

Ghana has largely experienced stable and consistent economic growth since 1960. The size of the Ghanaian economy has expanded by nearly 97 percent with the GDP increasing from USD1.2 billion in 1960 to USD 35.9 billion in 2012 in real terms (Ministry of Finance, 2012). The expanding trend in the economy corresponds to the increasing energy and greenhouse gas emission intensities especially in the last couple of years (see table 1). As the economy expands and population grows, lots of energy resources are utilized to meet the growing demand in industry, transport and households.

Ghana attained Lower Middle Income Country (LMIC) bracket in November 2010 after rebasing the economy. With the revised GDP estimates, GDP per capita has increased from USD1, 067 in 2000 to USD 1,652 in 2011. In the past 20 years, growth has accelerated, averaging 6.4 percent per year over the past ten years, except in 2011, the GDP growth spiked at 14.4 percent after the addition of the oil and gas revenues (Ministry of Finance, 2012). The GDP (oil and non-oil) is projected to stabilize between 8-9 percent by 2015 because of the overall improvements in economic outputs of the productive sectors, which are (a) services (49.3 percent); (b) Industry (27.6 percent); and (c) Agriculture (23.1 percent) (GSS, 2012).

Figure 2: Relationship between CO_2 Emissions and Consumption



Source: www.cesarharada.com

Since the 1980s consumption has contributed immensely to GHG emissions especially CO_2 (see figure 2). This trend can be attributed to the expansion in the Ghanaian economy which is as a result of increase in demand for both consumable goods and energy by households as a result of increased population and urbanisation and also increased energy demand by industries.

Table 1: Macroeconomic indicators relevant to GHG emissions and removals in Ghana

	1990	*2000*	*2006*	*2010*	*2012*	*Change 1990–2012 (%)*	*Change 2010–2012 (%)*
Population (million)	14.43	18.91	21.93	24.66	25.91	79.8	8.7
GDP (Constant 2005 USD billion)*	5.51	8.39	11.42	14.80	18.52	236.2	67.5
TPES (Mtoe)**	5.29	7.74	9.06	9.32	11.77	122.49	26.29
Final Consumption (Mtoe)***	4.31	5.41	6.01	6.46	8.16	89.33	26.32
GHG emissions without AFOLU (Mt CO_2e)	*5.61*	*8.6*	*12.48*	*15.76*	*18.49*	*69.6*	*14.8*
GHG emissions with AFOLU (Mt CO_2e)	*13.93*	*15.64*	*23.19*	*28.73*	*30.85*	*54.8*	*10.9*
GDP per capita* (Current USD thousand)	0.4	0.26	0.93	1.33	1.6	300	20.3
TPES per capita (toe)	0.37	0.41	0.41	0.38	0.45	21.62	18.42
Final Consumption per capita (toe)	0.30	0.29	0.27	0.26	0.31	3.33	19.2
GHG emissions per capita (t CO_2e)	*0.39*	*0.45*	*0.57*	*0.64*	*0.71*	*82.05*	*10.9*
GHG emissions per GDP unit (kg CO_2e /2005 USD)	*1.02*	*1.03*	*1.09*	*1.06*	*1.00*	*-1.9*	*–6.2*
Energy Intensity (toe/2005 GDP)	*0.96*	*0.92*	*0.79*	*0.63*	*0.64*	*-33.3*	*1.59*

Source: NEEDS Country Report[2]

Achieving sustainable development is considerably paramount and remains an issue of great concern to Sub Saharan Africa (SSA) including Ghana. Interestingly, the quest to achieve sustainable development does not only require the coordination of the various sectors of the economy but also entails the use of various policy tools. This is particularly imperative because beside the fact that sustainable growth is argued to depend on a number of factors including structural transformation, industrialization, trade openness, enhancing the competitiveness of the business environment, good governance, political stability, fiscal discipline among others; its promotion has several implications particularly for the sustainability and quality of the environment. Many countries in SSA like Ghana have attempted several policies, many of which are intended not only to inject growth into their economies but also to ensure sustainable growth without sacrificing the quality of the environment.

Ghana has been an energy-intensive economy for several decades. In 2011, Ghana attained a lower middle-income status with a per capita income of $1,594. The GDP per capita increased to $1,605 in 2012 with total GDP of nearly US$ 40.71billion in the same year. The GDP growth is projected to stabilize at 9 percent by 2015 onwards. Structural transformation of economy since 2006 has resulted in a shift from agrarian- to a service sector-led (49.9 percent). This is partly due to the realignment of

[2] Asante, et al. (2010), National Environmental, Economic and Development Study (Needs) For Climate Change: Ghana Country Report.

basket of activities under service sector. The significant growth in the economy has given rise to a 33 percent increase in the total national greenhouse gas emissions from 23.2MtCO_2e in 2006 to 30.8 Mt CO_2e in 2012.
Ghana is endowed with natural resources such as deposits of gold, diamond, manganese and bauxite. In addition, Ghana also has significant arable lands and forests, and recently commenced of commercial oil production. These are the major natural resource base that support economic growth of the country. Ghana's major export commodities are crude oil, cocoa, minerals, timber and electricity. In 2011, the total oil production was estimated at 24,195,895 barrels (average of 66,290 barrels per day) all of which were lifted offshore. According to Energy Commission (2011), a total of 2,220,546.09MMBtu (equivalent to 56 ktoe) of associated gas were produced from the oil fields some of which were either rejected or flared. Latest estimates put the cost of environmental degradation at 9.4 percent of GDP.

The major goals of Ghana's long-term sustainable development as a middle income country by 2020 has embedded some environmental objectives which are built on the following foundations: to establish and maintain a sound built and natural environment that can sustain productive economic activities and pleasant living conditions for both present and future generations; and to establish an environmentally conscious society that can exercise self-discipline at all times with regard to individual and community behaviours towards the environment.

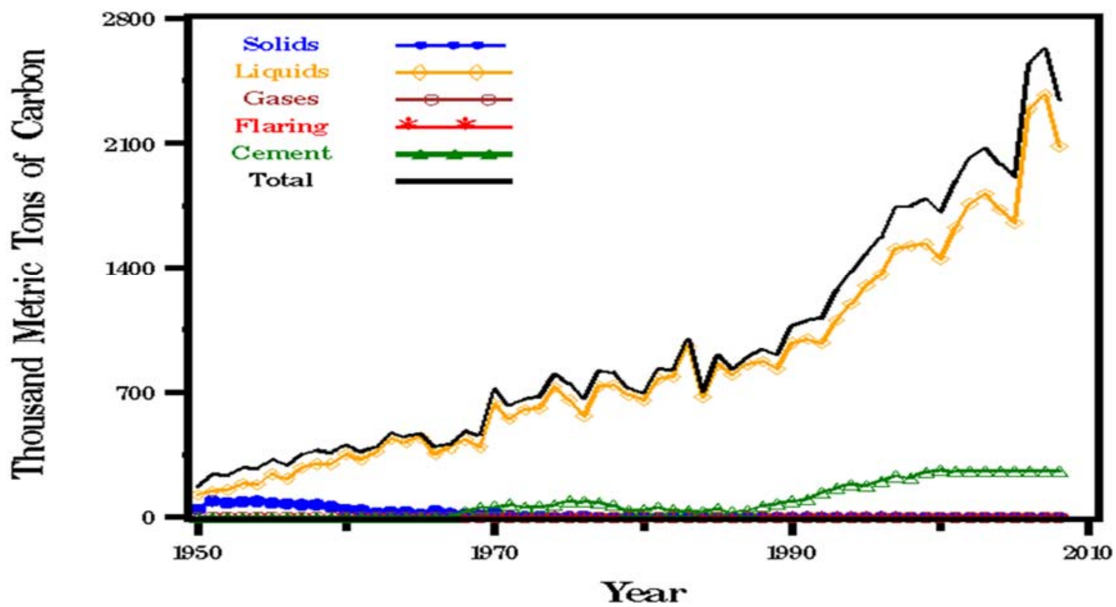
Ghana's blue print for sustainable socio-economic development is the Vision 2020 document put together by the National Development Planning Commission (NDPC). The document recognizes the fact that the only means by which the country's resources can be used efficiently to achieve rapid economic growth while maintaining the integrity of the environment hinges on the integration of Science and Technology in the various programmes. Ghana has signed and ratified all the global conventions related to environment and sustainable development. The implementation of these conventions have been integrated into the country's development programmes. Ghana participates in fora on the global convention related to sustainable development.

According to the High Emission Scenario (HES), it is suggested that by 2025 Ghana, Nigeria and Sierra Leone will emit 4.4, 5.4 and 1.2 million tons of carbon respectively. This would amounts to seven, six and four folds increase over present emissions. However, emissions can be reduced by 36 percent, 25 percent and 13 percent respectively if adequate measures to conserve carbon are introduced as contained in the Low Emission Scenario (LES) strategies (Omojolaibi, 2010).

3.2 Current Status of GHG Emissions

On a list of countries by CO_2 emissions per capita for the period 1990 – 2009, Ghana is ranked 176th among 214 countries[3]. Inventory of GHG emissions in Ghana indicate that carbon dioxide accounts for the largest share of Ghana's greenhouse gas emissions by sources. On the other hand, carbon sinks in forested and afforested lands offset the total CO_2 emissions which then make Ghana a net CO_2 removal by sinks. Greenhouse Gases such as CO_2, CH_4 and N_2O emitted by different sources increased by 6.6 percent, 14.7 percent and 12 percent respectively from 1990-1996. The carbon dioxide equivalent (CO_2e.) was estimated based on Global Warming Potential (GWP) of CO_2, CH_4 and N_2O. The results also indicate that total methane emissions are lower than CO_2 emissions. However, the CO_2 equivalent of CH_4 was about 2-3 times higher than CO_2 assuming global warming potential of 24.5 for CH_4. Methane emissions are largely due to agriculture and biomass burning for energy. Nitrous oxide (N_2O) contributed just about 6.8 percent of the total CO_2 equivalent emissions for 1994. The main sources of N_2O emissions are agriculture (65 percent), biomass combustion (26 percent), human waste (5 percent) and land use change and forestry and grassland conversion (4 percent).

Figure 3: CO_2 Emissions in Ghana by Sector



Source: CDIAC[4]

[3] https://en.wikipedia.org/wiki/List_of_countries_by_carbon_dioxide_emissions_per_capita
[4] Carbon Dioxide Information Analysis Centre, U.S Department of Energy http://cdiac.ornl.gov/trends/emis/gha.html

3.3 Projections of GHG emissions at 2020 and 2050 time horizons under the Business-As-Usual Case

The energy sector in Ghana is currently the largest emitter of GHG. Projection of GHG emissions by the National Communication (2000) indicate that CO_2 equivalent emissions would increase from 7,278 Gg to 118,405 Gg between 1994 and 2020, move up to 234,135 Gg by 2030, and then to 519,826 Gg by 2050 (see table 2.3).

Table 2: Projections of CO_2 Equivalent GHG Emissions under the Business-As-Usual Scenario

Year	1994	1996	2000	2004	2008	2020	2030	2050
Biomass consumed TJ	233033.10	2975550.97	485163.67	791046.56	1289780.54	5590583.56	10515000.22	22828048.99
CO_2 emissions from fossil fuels (Gg)	3048.40	3892.50	6343.62	10348.00	16872.14	73132.68	146263.63	328505.93
Methane emissions from biomass (Gg)	155.80	198.94	324.37	528.87	862.31	3737.72	7475.29	16789.35
Nitrogen oxide emissions from biomass (Gg)	0.80	1.02	1.67	2.72	4.43	19.19	38.38	86.20
CO_2 equivalent of CH_4 (Gg)	3817.00	4873.93	7946.81	12957.06	21126.15	91571.78	183140.05	411328.81
CO_2 equivalent of N_2O (Gg)	256.00	326.89	532.98	869.01	1416.90	6141.57	9125.76	20382.38
Business-As-Usual CO_2 equivalent	7278.00	9093.32	14826.41	24174.07	39415.19	118404.87	234135.02	519825.62

Source: NEEDS Country Report[5]

3.4 Abatement Scenarios at 2020 and 2050 Time Horizons

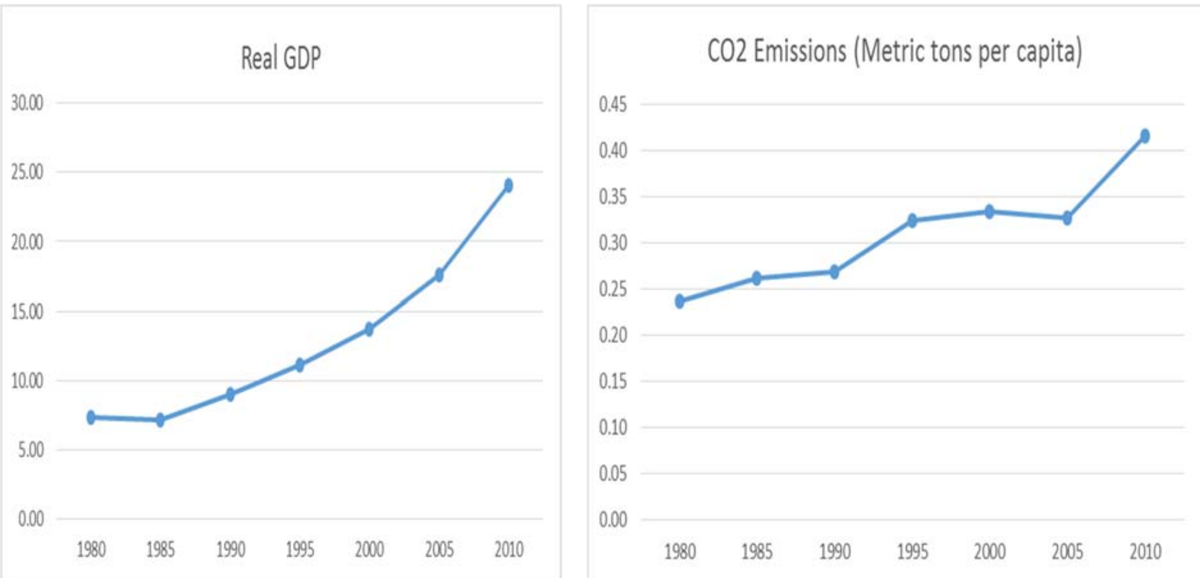
Abatement scenarios under climate change in Ghana has principally focused on two major sectors that were potential sources for greenhouse gas emissions and reductions according to the National Communication (2000). Greenhouse Gas inventory results showed that the Energy Sector was responsible for the highest emissions of CO_2 while the Forestry Sector emerged as the potential for increasing the country's carbon sink base.

The major driving force of the broad policy framework in Ghana has been geared towards achieving a level of industrialisation which provides significant employment opportunities and economic diversification as a priority and becoming a middle income level industrial country by the year 2020. This requires substantial financial investments and energy inputs. The rate of electrification presents

[5] Asante, et al. (2010), National Environmental, Economic and Development Study (Needs) For Climate Change: Ghana Country Report.

the challenge of providing energy in a suitable form to a large population (both urban and rural) while at the same time minimizing GHG emissions and maximising carbon sequestration (carbon dioxide-fixing by vegetation). Switching the form of energy used by the poor in the urban areas from charcoal to kerosene or LPG can reduce the rate of deforestation due to the reduced demand for biomass for fuelwood or charcoal. The impact of climate change on energy and industrial production has already started manifesting with the most conspicuous being the effect of highly variable precipitation patterns on hydro power generation. Other effects of climate change on development in Ghana are a decrease in biomass production especially as a result of decreased precipitation and increased temperatures in some areas to water stress on woody plants and also to general land degradation. Another impact of climate change is the decrease in agricultural productivity due to changing agro-ecological zones, lack of water for irrigation, and outbreaks of pests and diseases which are likely to decrease the amount of biomass available for energy (NEEDs Country Report, 2010).

Figure 4: CO_2 Emission and Real GDP (1980-2011)



Source: Author

While Ghana's real GDP has been growing at a steady rate, CO_2 emissions depict a chequered growth trend. Real GDP averaged USD 21.58 billion over the period 2005-2011. That same period saw CO_2 emissions averaging 0.39 metric tons per capita. In 2011 when Ghana lifted her first Oil, Real GDP increased by USD 3.39 billion over USD 24.1 billion is 2010, however, CO_2 emission decreased 0.02 from 0.42 to 0.40 during the same period.

4 DATA DESCRIPTION, MEASUREMENT AND METHODOLOGY

4.1 Data Sources, Data Description and Diagnostic Statistics

The data for this study was sourced from secondary sources such as the World Bank's World Development Indicators (WDI) and the United Nations Statistical Division.

Carbon Dioxide (CO_2): This measures the emissions stemming from the burning of fossil fuels and the manufacture of cement. They include carbon dioxide produced during consumption of solid, liquid, and gas fuels and gas flaring. It is measured in metric tons per capita which refers to emissions per unit/person. This data was sourced from the World Bank's WDI database. It is the dependent variable.

Real Gross Domestic Product (GDP): It is sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. It is measured in constant 2005 U.S. dollars and was sourced from the World Bank's WDI database. It measures the total economic activity of a country and is expected to impact positively on CO_2 emissions. However, it is expected that GDP squared will impact negatively on CO_2 emissions.

Energy Consumption (ENC): This refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport. It is measured in measured in kilograms of oil equivalent per capita. Data was sourced from the World Bank's WDI database. Since economic activity is stimulated with an increase in energy consumption; it is expected that Energy Consumption will impact positively on CO_2 emissions.

Foreign Trade Ratio (FTR): This is the measure of the sum of all imports and exports to GDP. It is an indicator of how liberalised and opened an economy is to the rest of the world in terms of trade and other economic activities. It is used as a measure of trade openness of an economy. It is measured as a ratio of the sum of exports and imports to GDP. The literature is not conclusive on the a priori sign of foreign trade on CO_2 emissions; it can be positive or negative.

4.2 Theoretical Context of the Model

The choice between linear and log-linear models to analyse the relationship between the environment and growth has been a matter of interest in the econometric literature according to Zhou et al. (2010). On conceptual grounds, linear models yield constant marginal effects and variable elasticities, while the log-linear models does the opposite. In the EKC literature, no consensus is reached on which model is better. For the purpose of this study, the linear model is chosen because of the easy interpretability of the coefficients and computational simplicity.

The classical EKC model is specified as below;

$$CO_{2_t} = f(GDP_t, GDP_t^2) \quad (1)$$

4.3 Empirical Methodology

4.3.1 Model Specification

The study adopts the standard EKC model as adopted by Zawada, et. al. (2014) to study the relationship between environmental pollutant and economic growth in Poland. They added only energy consumption but this study two both energy consumption and trade openness to test the robustness of the results. The used quarterly data 2000-2012 but this study uses annual data from 1980-2011. The inclusion of energy consumption is necessary because as Ghana has transited into a lower-middle income country her energy consumption level has also increased. The inclusion of trade openness is premised on the evidence that Ghana's attempt at promoting economic growth has attracted more FDI and trade than most SSA countries. Ghana's stable democracy and conducive business environment has made her the "*Gateway*" and destination of FDI in Africa. Multinational companies relocate from developed countries with stricter environmental regulations to developing economies where environmental regulation are less strict. Additionally, the covers a relatively longer period including the period 2010 and 2011 when Ghana started commercial production of Oil and Gas leading to the subsequent flaring of gas which positively impact on carbon emissions.

The model specification is given as below;

$$CO_{2_t} = f(GDP_t, GDP_t^2, Z_t) \quad (2)$$

C_t represents environmental degradation and it is a function of Y_t which represents economic activity and Z_t which captures other structural and institutional explanatory variables that contribute to degradation of the environment. In this study C_t is proxied by CO_2 emissions per capita, Y_t is captured by Real GDP and Z_t represents total energy consumption and openness to trade. The relationship can be specified as;

$$CO_{2,t} = \alpha_0 + \alpha_1 RGDP_t + \alpha_2 RGDP_t^2 + \alpha_4 ENC_t + \alpha_5 FTR_t + \varepsilon_t \quad (3)$$

Where;

α_0 = Constant

α_1 to α_5 = Coefficients

$CO_{2,t}$ = Carbon dioxide Emission per capita

$RGDP_t$ = Real GDP

$RGDP_t^2$ = Square of Real GDP

ENC_t = Energy consumption

FTR_t = Trade Openness

ε_t = Stochastic term

The turning point of per capita real GDP; Y* = exp. (- $\alpha_1/2\alpha_2$)

Table 3: Expected signs of Variables and Interpretation

Variable	Expected Sign	Interpretation
GDP	α_1<0, α_2>0	Inverted U-Shaped Relationship (EKC Confirmed)
	α_1>0, α_2<0	U-Shaped Relationship (EKC not Confirmed)
ENC	α_3>0	Increase in energy usage leads to increase in CO_2 emissions
FTR	α_4<0	If production of pollutant intensive items is reduced due to enforcement of environmental protection laws.
	α_4>0	If dirty industries of developing economies are busy producing a heavy share of CO_2 emissions with their production processes. It also confirms the pollution haven hypothesis.

4.4 Estimation Technique

The study adopts econometric techniques to analyse the variables. The exogenous variables, GDP per capita, Foreign Trade Ratio and Energy Consumption are regressed on the endogenous variable CO_2 Emission per capita using Eviews software version 9. The first task in time series econometric analysis is to determine the stationarity of the variables. The Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) tests are used to verify the stationarity and order of integration of the variables. Since all the variables are not stationary at levels, the Johansen method is used to test for cointegration among the variables for which the results showed that the variables are cointegrated. This is done to avoid any spurious relationship and also confirm a long-run relationship among the variables.

4.4.1 Unit Root Test

To ensure that the variables are stationary or otherwise, Unit Roots test was conducted the presence of a Unit Root renders a series non-stationary. Secondly, Unit Root testing helps to avoid spurious regressions where the model indicates promising diagnostic test results but the regression analysis has no meaning (Gujarati, 2003). There are various approaches for testing for the presence of a Unit Root but this study adopted two of the approaches that are commonly used by researchers; the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) tests (see Table 4).

Table 4: Results of Unit Root Tests

Series	ADF(Level)		PP(Level)		ADF(1st Diff.)		PP(1st Diff.)	
	C	CT	C	CT	C	CT	C	CT
CO_2	-0.0180	-4.2317***	-1.6272	0.0121***	-6.4024***	-6.3682***	-14.3559***	-14.4677***
ENC	-2.0660	-0.0108***	-2.2487	-2.8847	-4.2546***	-4.4101***	-5.2994***	-6.8318***
FTR	-1.163	-3.5625**	-1.1463	-3.4094*	-5.4956***	-5.6133***	-6.8336***	-7.3106***
GDP	2.6799	0.2319	2.6799	-2.8042	-4.6491***	-5.8120***	-1.6772	-2.6625
GDP^2	2.9142	0.6219	2.9142	-2.4728	-4.0256***	-5.1982***	-1.4835	-2.5897

Source: Author's computation from Eviews 9
Note: 1. C = Constant; CT = Constant and Linear Trend
2. ADF and PP are based on Mackinnon critical values. (***), (**) and (*) indicate statistical significance at 1%, 5% and 10% respectively.

Table 4.2 reports the results of the Augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) test statistics at levels and first difference. From the results we observe that all the variables attained stationarity after first differencing and are, therefore, integrated of order one, that is I(1), implying the data will be analysed using their first difference. This necessitated a cointegration test to establish a long-run relationship among the variables.

4.4.2 Cointegration Test

The concept of cointegration implicitly assumes linearity and symmetry, what means that the adjustment of the deviations towards the long-run equilibrium is made instantaneously at each period and increases or decreases of the deviations are corrected in the same way. The test of cointegration is basically to establish a long-run stable equilibrium or stationary relationship between non-stationary series (Zawada et. al., 2014). The notion of cointegration is when variables in a hypothesized relationship should not depart from each other in the long-run or if they do diverge in the short-run, the divergence should diminish in the long-run so that the series will be on the same path. The Johansen Cointegration test is preferred because it allows for the easy correction of serial correlation. If EKC regressions do not cointegrate then the estimates will be spurious. Very few studies have reported any diagnostic statistics for integration of the variables or cointegration of the regressions and so it is unclear what we can infer from the majority of EKC studies (Stern et al., 2003).

Table 5: Results of Johansen Cointegration Test

No. of Cointegrating Equations	Trace Test		Max-Eigenvalue Test	
	Trace Statistic	**5% Critical Value**	**Max-Eigen Statistic**	**5% Critical Value**
*None**	145.6375	69.8189	69.2534	33.8769
*At most 1**	76.3841	47.8561	42.4628	27.5843
*At most 2**	33.9214	29.7971	21.2644	21.1316
At most 3	12.6570	15.4947	10.9579	14.2646
At most 4	1.6991	3.8415	1.6991	3.8415

Source: Author's computation from Eviews 9
Note: (*) indicates cointegrating equations at the 5% critical level

This study employs the Johansen approach to cointegration test and the results of both the trace test and the Max-Eigenvalue indicate three cointegrating equations at the 5 percent (Annex 4). This shows that at most three of the variables have a long run association or equilibrium between each other. Hence, the null hypothesis of "no cointegration" is rejected and the alternative hypothesis of "cointegration" is accepted at the 5 percent level. The null hypothesis can be rejected if and only if the number of cointegrating equations is greater than one. In this case we accept the two cointegrating equations, hence, the null hypothesis of "no cointegration" can be rejected.

4.4.3 Error Correction Model

The study accounts for the short-run dynamics as well as the long-run equilibrium relationship by using an Error Correction Model (ECM). There are two (2) types of the ECM; the Hendry ECM model and the Engle-Granger ECM model. This study adopted the Hendry method of ECM because it is easier and less complex.

The general mathematical formulation of the Hendry ECM model is as shown below:

$$\Delta Y_t = \lambda_0 + \lambda_1 \Delta X_{1t} + \lambda_2 \Delta X_{2t} + ... + \lambda_k \Delta X_{kt} + \beta_0 Y_{t-1} + \beta_1 X_{t-1} + \beta_2 X_{t-2} + ... + \beta_k X_{t-k} + \mu_t \quad ... (4)$$

$$\Delta Y_t = \lambda_0 + \sum_{i=1}^{k} \lambda_1 \Delta X_{it} + \beta_0 Y_{t-1} + \sum_{j=1}^{k} \beta_j X_{jt-1} + \mu_t \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

Where;

λ_0 = constant

β_0 = error correction coefficient (validates the long-run relationship)

$\lambda_1, \lambda_2, ...\lambda_k$ = short-run model

$\beta_1, \beta_2, ...\beta_k$ = long-run model

Hence the linear specification of the error correction model is as below:

$$D(CO_2) = \alpha_0 + \alpha_1 D(GDP) + \alpha_2 D(GDP^2) + \alpha_3 D(ENC) + \alpha_4 D(FTR) + \alpha_5 CO_2(-1) + \alpha_6 GDP(-1)$$
$$+ \alpha_7 GDP^2(-1) + \alpha_8 ENC(-1) + \alpha_9 FTR(-1) + \mu_t \ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where;

D = Difference operator, defined as $D(X)_t = X_t - X_{t-1}$

α_0 = Constant

μ_t = Error term

α_5 = Equilibrium Correction Coefficient

α_1 to α_4 = Coefficients of the Short-run model

α_6 to α_9 = Coefficients of the Long-run model

Table 6: Results of the Vector Error Correction Model
Dependent Variable: D(CO_2), Sample (adjusted): 1981 – 2011

Short-run Model				Long-run Model			
Variable	Coefficient	t-stat	Prob.	Variable	coefficient	t-stat	Prob.
C	-38.1962	-4.2086	0.0004***	CO2(-1)	-1.2202	-6.7940	0.0000***
D(RGDP1)	-20.9571	-1.9134	0.0694*	RGDP1(-1)	28.5670	4.1557	0.0004***
D($RGDP^2$)	4.1366	1.9640	0.0629*	$RGDP^2$(-1)	-5.2580	-4.0689	0.0006***
D(ENC)	-0.0381	-4.1709	0.0004***	ENC(-1)	-0.0312	-2.9428	0.0078***
D(FTR)	0.0368	1.2225	0.2351	FTR(-1)	0.0508	1.4800	0.1537
R^2	0.7434	DW-Stats	2.1735	F-Stats	6.7598	Prob(F-stat)	0.0002
Adj. R^2	0.6334	No. of obs.	31				

Source: Author's computation from Eviews 9
Note: (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively.

4.4.4 Granger Causality Tests

Granger causality test is widely used in econometric studies to establish the direction of causality between or among variables. This test is normally preferred to other tests because it is very robust. The Granger causality technique was proposed by Granger (1969) and subsequently modified by Toda and Yamamoto (1995).

This study attempts to establish the direction of causality between CO_2, Energy consumption, GDP and Foreign Trade Ratio in Ghana.

$$Y_t = \beta_0 + \sum_{i=1}^{d} \gamma_{1i} Y_{t-1} + \sum_{i=1}^{d} \delta_{1i} X_{t-1} + \eta_{1t} \quad \text{.. (4)}$$

$$X_t = \beta_0 + \sum_{i=1}^{d} \gamma_{2i} X_{t-1} + \sum_{i=1}^{d} \delta_{2i} Y_{t-1} + \eta_{2t} \quad \text{.. (5)}$$

Equation (4) hypothesises that current Y is related to past lagged values of X and itself and equation (5) also hypothesises that current X is related to past lagged values of Y and itself. Where *d* is an assumed autoregressive lag order of the variables in the system and η_1 and η_2 are assumed to be white noises. Each variable is regressed on each other variable lagged from 1 up to *d* lags in the system. For the granger causality test, four (4) scenarios must be considered before establishing the direction of causality. The scenarios are as indicated below;

i. For unidirectional causality from X to Y, the estimated coefficient of the lagged X in equation (4) must be statistically different from zero, that is, $\delta_1 \neq 0$ and the coefficient of the lagged Y is equation (5) is not statistically different from zero, that is $\delta_2 = 0$.

ii. For unidirectional causality from Y to X, the estimated coefficient of the lagged Y in equation (5) must be statistically different from zero, that is, $\delta_2 \neq 0$ and the coefficient of the lagged X is equation (4) is not statistically different from zero, that is $\delta_1 = 0$.

iii. For bi-causality or feedback effect, the estimated coefficient of the lag of both X and Y are statistically different from zero in equations (4) and (5); that is $\delta_1 \neq 0$ and $\delta_2 \neq 0$.

iv. For independence or non-causality in either direction, the estimated coefficients of the lag of both X and Y in both equation (4) and (5) are not statistically different from zero, that is $\delta_1 = 0$ and $\delta_2 = 0$.

Table 7: Results of Pairwise Granger Causality Test (Lags 2)

Direction of Causality	Probability	Direction of Causality	Probability
CO_2 → GDP	0.3133	GDP → ENC	0.0041***
GDP → CO_2	0.0304**	ENC → GDP	0.2474
GDP → FTR	0.0042***	ENC → CO_2	0.0149***
FTR → GDP	0.9206	CO_2 → ENC	0.1516
CO_2 → FTR	0.0356**	ENC → FTR	0.7894
FTR → CO_2	0.1804	FTR → ENC	0.1425

Source: Author's computation from Eviews 9
Note: (***), (**) and (*) indicate significance at 1%, 5% and 10% respectively

4.4.5 Diagnostic Tests

In order to validate the model, various diagnostic tests were conducted; the residual diagnostic tests (Normality test, Heteroscedasticity (Arch) and Breusch-Godfrey Serial Correlation LM Test); stability diagnostic tests (Ramsey RESET test, CUSUM and CUSUM of Squares tests). These tests proved that the model is stable and has no serial correlation or normality setbacks. In view of the fact that the model has been validated through the various diagnostic tests, it can be concluded that the model is good and can be adopted for policy and forecasting.

4.5 Empirical Findings and Analysis of Results

4.5.1 Findings from the ECM

The ECM is to check the long-run relationship among the variables. Based on the results obtained from the estimation of the ECM the following statistical inferences can be made;

From Table 4.4, it can be observed that GDP, GDP^2, energy consumption and trade openness explain about 74 percent of variations in carbon emissions. This is depicted by an R^2 of 0.7434. The probability of the F-statistic is significant at 5 percent implying that the model fit is good and the Durbin-Watson statistic of 2.1735 indicate that the errors are not correlated.

The equilibrium correction coefficient, $CO_2(-1)$, has the required negative sign and is highly significant at 1 percent, hence, the ECM model is valid and confirms the long-run relationship between CO_2 emissions and GDP between the period 1980 to 2011. This suggest that in the event of a disequilibrium in the short-run, it will be rectified at a fairly high speed of 122 percent annually.

The estimated results indicate that in the short-run, it was significantly revealed that RGDP is negatively related to CO_2 emissions while $RGDP^2$ is positively relatively related to CO_2 emission indicating a U-shape relationship (EKC hypothesis not confirmed). This means that in the short run initial growth reduces CO_2 emission to a certain income level beyond which further growth increases CO_2 emissions. In the long-run, RGDP is positive and significant while $RGDP^2$ is negative and significant. This indicates an inverted U-shape relationship (EKC hypothesis confirmed). This findings confirm that EKC is a long-run phenomenon in Ghana. This means in the long-run, initially GDP growth causes CO_2 emissions to rise beyond a turning point, after which further growth in GDP causes a fall in CO_2 emissions. These findings contradicts Omojolaibi (2010) who failed to confirm the EKC hypothesis for Ghana, Nigeria and Sierra Leone in a panel study. However, it conforms to the finding of Lean and Shabaz (2012) who confirmed the EKC hypothesis for Pakistan in a long-run model. This confirms that the EKC hypothesis is becoming evident in developing economies contrary to earlier views. According to Dasgupta, et. al. (2002), developing countries are addressing and even remedying the pollution problem, hence, the evidence of the EKC in developing countries. Trade openness has a positively related to CO_2 emissions both in the short and long-run though the impact is not statistically significant, hence, this study does not confirm the pollution haven hypothesis in Ghana. Energy consumption is highly significant at 1 percent and is negatively related to CO_2 emission though impact is small both in the short and long-run. If energy consumption increase by 1 percent, CO_2 emissions will decrease by 0.04 percent in the short-run and 0.03 in the long-run. This contradicts Lean and Shabaz (2012) who found a positive relationship between energy consumption and CO_2 emissions both in the short and long-run. The significantly negative impact of energy consumption on CO_2 emissions attest to the fact that the Renewable Energy Policy being implemented by government to ensure that 10 percent of energy generation is from renewable sources is a step in the right direction. Also the Renewable Energy Fund and the new Feed-in-Tariff (FIT) has contributed to the reducing emissions from energy consumption.

4.5.2 Findings from Pairwise Granger Causality Test

The pairwise granger causality test is to check the direction of causality among the variables. The results from the granger causality test indicates only a uni-directional causality from GDP to CO_2 and this confirms the confirms the existence of EKC; GDP to trade openness; CO_2 to trade openness which means weak environmental regulations will attract highly polluting firms from abroad; GDP to energy consumption and finally from energy consumption to CO_2 emissions which means Ghana's energy policy must encourage the use of renewable energy to curb CO_2 emissions.

5 CONCLUSION AND POLICY IMPLICATIONS

5.1 Conclusion

The study investigates the relationship between CO_2 emissions, economic growth, energy consumption and trade openness in Ghana over the period of 1980 to 2011. The result suggests that there exists a long-run relationship among the variables. The positive sign of GDP and negative sign of GDP^2 confirms that EKC hypothesis is supported in the country. Energy consumption decreases CO_2 emissions in both short and long run. Openness to trade was found to be insignificant both in the short and long run. The result of Granger causality test shows a one-way causal relationship running from income and energy consumption to CO_2 emissions; GDP to energy consumption and trade openness; and CO_2 emissions to trade openness.

5.2 Policy Recommendation

a. Sustainable Development

The significant existence of EKC shows that the country's effort to reduce CO_2 emissions and pursue sustainable development pathways. This indicates the reasonable achievement of controlling environmental degradation in Ghana. The recent launching of the National Climate Change Policy and the National Environmental Policy in 2014 will solidify the country's effort towards sustainable development by reducing emissions. However, findings based on aggregate data may not be able to show the emission patterns of the ten individual regions in the country. It must be emphasised that the implementation of these policies are a necessary but not a sufficient condition. The need for effective enforcement of environmental laws and regulation is paramount not only at the national but also the regional and district levels to prevent the "*pollution haven hypothesis*". Furthermore, research and development activities on environmental degradation which are important to attain sustainable development must be strongly pursued in Ghana. Therefore, to curb CO_2 emissions, there is a need to implement environmental taxes such as green tax.

b. Promote the use of Renewable Energy

The significantly negative impact of energy consumption on CO_2 emissions attest to the fact that the Renewable Energy Policy being implemented by government to ensure that 10 percent of energy generation is from renewable sources is a step in the right direction and must be implemented to the latter. Also the establishment of the Ghana Gas Company to use the gas from the oil fields will make gas flaring a thing of the past and reduce CO_2 emission. The gas can also be used for domestic and industrial purposes and this will reduce emissions further. The removal of huge subsidies on fossil fuel should create fiscal space for government to aggressively implement the renewable energy policy. Government together with UNEP has developed Low Emissions Development Strategies (LEDS) in various sector to help reduce emissions in Ghana and these strategies must be implemented. Last but not least, government must see to the successful implementation of the Environmental Fiscal Reforms which aims at setting up a Climate Change Fund to be dedicated to the implementation of the National Climate Change Policy and other environmental activities.

5.3 Limitation and Further Study

The study limited the scope of environmental degradation to only the emission of CO_2 and did not consider other GHGs that relevant measures of environmental degradation such as nitrogen oxide (NO_2), sodium oxide (SO_2) and Biochemical Oxygen Demand-BOD (a measure of pollution of water bodies) as a result of data limitations. The data for all the variables of interest in the study retrieved from the World Development Indicators (WDI) database was up to 2011 due to non-availability of data for some variables beyond this period. Further researchers should use regionally disaggregated emissions data to attain a comprehensive impact which will provide new insights to policy makers in controlling degradation at the regional and district levels. Also other forms of GHGs should be used to investigate the EKC hypothesis in Ghana.

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ANNEXES

Annex 1: Working Data

Year	CO_2	GDP	GDP^2	FTR	ENC
1980	0.24	7.29	53.18	0.85	7.70
1981	0.27	7.04	49.52	0.78	7.30
1982	0.26	6.55	42.90	0.66	7.10
1983	0.31	6.25	39.07	0.51	4.50
1984	0.21	6.79	46.12	0.50	3.90
1985	0.26	7.14	50.94	0.55	4.30
1986	0.23	7.51	56.37	0.62	5.50
1987	0.24	7.87	61.91	0.68	5.90
1988	0.25	8.31	69.07	0.66	6.30
1989	0.23	8.73	76.28	0.67	6.80
1990	0.27	9.02	81.44	0.69	6.50
1991	0.27	9.50	90.27	0.72	6.60
1992	0.26	9.87	97.41	0.72	7.00
1993	0.29	10.35	107.09	0.81	6.40
1994	0.31	10.69	114.27	0.80	6.80
1995	0.32	11.13	123.86	0.87	6.80
1996	0.34	11.64	135.53	0.98	7.00
1997	0.36	12.13	147.14	0.98	6.80
1998	0.36	12.70	161.30	0.91	5.20
1999	0.36	13.26	175.80	1.13	6.20
2000	0.33	13.75	189.05	1.89	7.50
2001	0.36	14.30	204.48	1.14	7.30
2002	0.38	14.94	223.30	0.97	6.60
2003	0.38	15.72	247.13	1.05	6.20
2004	0.35	16.60	275.58	0.98	7.00
2005	0.33	17.58	309.06	0.99	7.10
2006	0.43	18.71	349.88	1.08	7.00
2007	0.44	19.52	380.96	1.22	6.00
2008	0.40	21.30	453.86	1.37	6.80
2009	0.33	22.34	498.91	1.27	7.50
2010	0.42	24.10	580.85	1.42	8.30
2011	0.40	27.49	755.49	1.73	8.50

Source: World Development Indicators CD-Rom (2015); United Nations Statistical Division-National Accounts

CO_2 (Metric tons per capita)
GDP ($US Constant 2005)
$RGDP^2$ ($US Constant 2005)

ENC (kg oil equivalent per capita)
FTR (Ratio to GDP)

Annex 2: Results of Error Correction Model

Dependent Variable: D(CO2)
Method: Least Squares
Date: 02/03/16 Time: 01:21
Sample (adjusted): 1981 2011
Included observations: 31 after adjustments

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	-38.19618	9.075708	-4.208617	0.0004
D(Y1)	-20.95706	10.95264	-1.913425	0.0694
D(Y2)	4.136595	2.106260	1.963953	0.0629
D(ENC)	-0.038140	0.009144	-4.170942	0.0004
D(FTR)	0.036793	0.030098	1.222455	0.2351
CO2(-1)	-1.220151	0.179594	-6.793954	0.0000
Y1(-1)	28.56699	6.874224	4.155668	0.0004
Y2(-1)	-5.257952	1.292242	-4.068859	0.0006
ENC(-1)	-0.031161	0.010589	-2.942819	0.0078
FTR(-1)	0.050832	0.034345	1.480031	0.1537

R-squared	0.743396	Mean dependent var	0.005401
Adjusted R-squared	0.633424	S.D. dependent var	0.039445
S.E. of regression	0.023882	Akaike info criterion	-4.375668
Sum squared resid	0.011978	Schwarz criterion	-3.913092
Log likelihood	77.82286	Hannan-Quinn criter.	-4.224880
F-statistic	6.759812	Durbin-Watson stat	2.173548
Prob(F-statistic)	0.000156		

Annex 3: Pairwise Granger Causality Test

Pairwise Granger Causality Tests
Date: 02/03/16 Time: 01:59
Sample: 1980 2011
Lags: 2

Null Hypothesis:	Obs	F-Statistic	Prob.
ENC does not Granger Cause CO2	30	4.99741	0.0149
CO2 does not Granger Cause ENC		2.03611	0.1516
FTR does not Granger Cause CO2	30	1.83542	0.1804
CO2 does not Granger Cause FTR		3.82379	0.0356
GDP does not Granger Cause CO2	30	4.03161	0.0304
CO2 does not Granger Cause GDP		1.21625	0.3133
FTR does not Granger Cause ENC	30	2.10849	0.1425
ENC does not Granger Cause FTR		0.23871	0.7894
GDP does not Granger Cause ENC	30	6.89522	0.0041
ENC does not Granger Cause GDP		1.47791	0.2474
GDP does not Granger Cause FTR	30	6.88109	0.0042
FTR does not Granger Cause GDP		0.08301	0.9206

Annex 4: Johansen Cointegration Test

Date: 02/03/16 Time: 01:41
Sample (adjusted): 1984 2011
Included observations: 28 after adjustments
Trend assumption: Linear deterministic trend
Series: CO2 ENC FTR Y1 Y2
Lags interval (in first differences): 1 to 3

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.915697	145.6375	69.81889	0.0000
At most 1 *	0.780527	76.38414	47.85613	0.0000
At most 2 *	0.532073	33.92136	29.79707	0.0158
At most 3	0.323859	12.65697	15.49471	0.1280
At most 4	0.058877	1.699088	3.841466	0.1924

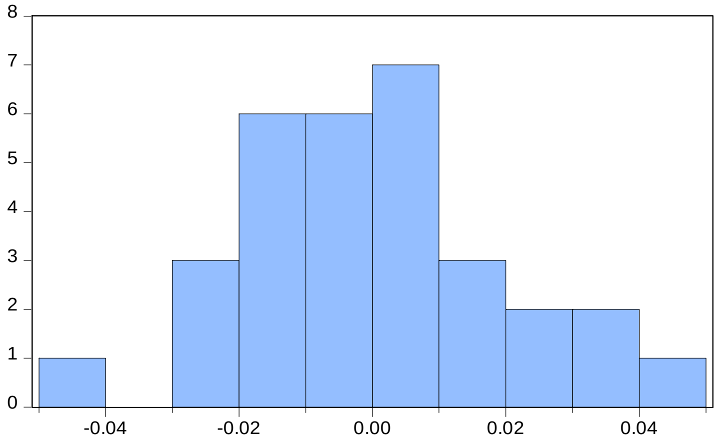
Trace test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Unrestricted Cointegration Rank Test (Maximum Eigenvalue)

Hypothesized No. of CE(s)	Eigenvalue	Max-Eigen Statistic	0.05 Critical Value	Prob.**
None *	0.915697	69.25335	33.87687	0.0000
At most 1 *	0.780527	42.46278	27.58434	0.0003
At most 2 *	0.532073	21.26439	21.13162	0.0479
At most 3	0.323859	10.95788	14.26460	0.1563
At most 4	0.058877	1.699088	3.841466	0.1924

Max-eigenvalue test indicates 3 cointegrating eqn(s) at the 0.05 level
* denotes rejection of the hypothesis at the 0.05 level
**MacKinnon-Haug-Michelis (1999) p-values

Annex 5: Jarque-Bera Normality Test



Series: Residuals
Sample 1981 2011
Observations 31

Mean	-8.72e-15
Median	-0.000912
Maximum	0.040418
Minimum	-0.042730
Std. Dev.	0.019981
Skewness	0.241559
Kurtosis	2.773123
Jarque-Bera	0.367964
Probability	0.831951

Annex 6: Serial Correlation Test

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.394326	Prob. F(2,19)	0.6795
Obs*R-squared	1.235465	Prob. Chi-Square(2)	0.5392

Annex 7: Heteroskedasticity Test

Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	1.672022	Prob. F(9,21)	0.1589
Obs*R-squared	12.94085	Prob. Chi-Square(9)	0.1653
Scaled explained SS	5.264859	Prob. Chi-Square(9)	0.8106

Annex 8: Ramsey RESET Test

Ramsey RESET Test
Equation: UNTITLED
Specification: D(CO2) C D(Y1) D(Y2) D(ENC) D(FTR) CO2(-1) Y1(-1) Y2(
-1) ENC(-1) FTR(-1)
Omitted Variables: Squares of fitted values

	Value	df	Probability
t-statistic	0.070429	20	0.9446
F-statistic	0.004960	(1, 20)	0.9446
Likelihood ratio	0.007687	1	0.9301

Annex 9: CUSUM and CUSUM of Squares