EFFECTS OF TRADE OPENNESS AND ECONOMIC GROWTH ON CARBON DIOXIDE (CO_2) EMISSIONS IN GHANA

By

Eric Evans Osei Opoku B.A. (Hons.)

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DECLARATION

I hereby declare that this submission is my own work towards the MA and that, to the best of my knowledge, it contains no material previously published by another person nor material which has been accepted for the award of any other degree of the University, except where due acknowledgement has been made in the text.

Eric Evans Osei Opoku (PG5542611)

………………………………………… ……………………… ………..................

Student Name & ID Signature Date

Dr. George Adu

………………………………………… ……………………… ………..................

Supervisor Signature Date

Mr. J. Appiah-Nkrumah

………………………………………… ……………………… ………..................

Head of Department Signature Date

DEDICATION

To my dear mother Philomina Ama Agyekum, for her unflinching support, care and sacrifices throughout my educational life.

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I am most grateful to our Lord Jesus Christ for seeing me through my educational expedition and most especially my masters programme successfully. I owe my life and this thesis to Him.

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ABSTRACT

This study investigated the effect of trade openness and economic growth on carbon dioxide (CO_2) emissions in Ghana. Other variables considered were energy consumption and urbanization. It employed the use of annual time series data sourced from the World Bank's World Development Indicators from 1971 to 2009. The ADF test proved all the variables to be stationary after first differencing. The Johansen multivariate test for cointegration indicated a one cointegrating equation among the series. The study found evidence for the Environmental Kuznets Curve (EKC) in the long-run. It found a statistically significant positive relationship between trade openness and CO_2 emissions. It however found energy consumption (*EC*) and urbanization (*URBAN*) to have negative impact on CO_2 emissions in the long-run but positive impact in the short-run. The Granger Causality test revealed a unidirectional causality running from energy consumption to CO_2 emissions with no reverse causality observed.

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LIST OF ACRONYMS & ABBREVIATIONS

ADF Augmented Dicker-Fuller

AR Autoregressive

ARDL Autoregressive Distributed Lag

ASEAN Association of Southeast Asian Nations

CO_2 Carbon Dioxide

DF Dickey-Fuller

ECM Error Correction Model

EKC Environmental Kuznets Curve

ECT Error Correction Term

EPA Environmental Protection Agency

ERP Economic Recovery Programme

EU European Union

FDI Foreign Direct Investment

GDP Gross Domestic Product

GHGs Greenhouse Gases

Gg Gigagram

GIPC Ghana Investment Promotion Center

GSS Ghana Statistical Service

IEA International Energy Agency

IMF International Monetary Fund

IPCC Intergovernmental Panel on Climate Change

kg kilogramme

kt kilotonnes

MNCs Multinational Corporations

Mt metric tonnes

NAFTA North American Free Trade Agreement

NO_x Nitrogen Monoxide and Nitrogen Dioxide

O_3 Ozone

OECD Organization for Economic Cooperation and Development

OLS Ordinary Least Squares

PHH Pollution Haven Hypothesis

PM_{10} Particulate Matter

ppm Parts per million

SAP Structural Adjustment Programme

SO_2 Sulfur Dioxide

SBC Schwarz Bayesian Criterion

UN United Nations

USA United States of America

US-EPA United States Environmental Protection Agency

VAR Vector Autoregression

VECM Vector Error Correction Model

WB World Bank

WDI World Development Indicators

WMO World Meteorological Organization

^0C Degrees Celsius

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Climate change and global warming have been major concerns to environmentalists and governments of nations lately as a result of their consequences on human life and the environment. Carbon dioxide (CO_2) emission is the major cause of global warming (Narayan and Narayan, 2010) accounting for about 72% of emitted greenhouse gases (Sanglimsuwan, 2011). With human activities and changes in land use which are directly associated with economic growth and development, pollution (CO_2) emissions have increased significantly in the past century (Boopen and Vinesh, 2010). CO_2 emission has been increasing as a result of the growing usage of fossil fuels for the production of goods and services (Sharma, 2011). Increases in income and economic growth which may be the easiest measure of human advancement may harm the environment if growth is unchecked (Vutha and Jalilian, 2008).

Trade liberalization will affect the environment as a result of it increasing the scale of economic activities (increased production). It changes the composition of economic activities and also the technique of production (Grossman and Krueger, 1993). Environmental effect of trade, particularly in the form of greenhouse gas (GHG) emissions has become a very relevant topic in recent research works (Zhang, 2011). However the usage of energy has become all time imperative as a result of increased consumption, production, industrialization, trade and population. These activities exert increasing degrading pressure on the environment. Issues of the environment associated with the growing usage of energy have over the years dominated discussions on climate change and economic growth (Adom et al., 2012). Trade may cause the emission of CO_2 and on the whole cause an increase in global greenhouse gas (GHG) emissions (Wyckoff and Roop, 1994). Nearly one third of the world's CO_2 emissions are as a result of manufacturing and the rest are as a result of power generations and other activities (Grether et al., 2007).

According to the UN (2000), economies are progressively integrated in a global economic structure to the extent that everything required in the production of a final commodity may be sourced from around the world in a system enabled by strong communications and information technologies. As a result of trade openness and further interdependence on economies for trade, pressure is exerted on natural resources thereby affecting the environment. Georgescu-Roegen (1971) shares the view that increased economic activities majorly characterized by production and consumption produce vast quantities of waste by-products because they require the usage of larger inputs of energy and raw materials. As the extraction of natural resources surge, accumulation of waste and pollution will cause the environment to degrade (Panayotou, 2003).

A chunk of the world's environmental damage is as a result of growing scale of global economic activities in which international trade forms a considerable portion (UN, 2000). Trade liberalization is likely to increase trade volumes, expand economic activities and affect environmental quality (Vutha and Jalilian, 2008). Some empirical works suggest that trade openness has resulted in the acquisition of lower standards of the environment (Nadal and Wise 2004; Watkins and Fowler 2002). Emissions in a country's international trade measured as a percentage of its total emissions are increasing overtime (Su and Ang, 2011). Trade provides the platform for consumers to shift the pollution associated with their consumption to other countries

(Yunfeng and Laike, 2010). All other things being equal, trade leads to environmental degradation since it increases the size of the economy and this increases pollution (Dinda, 2004). The levels of emissions of CO_2 are closely related to social, economic and industrial factors (Adom et al., 2012).

CO_2 is emitted in a number of ways such as burning of oil, coal, gas, petrol and also deforestation (Sanglimsuwan, 2011). According to Munksgaard and Pedersen (2001) although production and goods circulation cause carbon emissions the most, it is the final demand that determines the greatest emissions. Most empirical works have confirmed that trade has significant effect on the emission of carbon (eg, Jayanthakumaran et al., 2012; Peters and Hertwich 2008, Wang and Watson 2007).

The most abundant GHG produced and emitted in Ghana is CO_2 (EPA, 2011). From 1989 to 2007, the emissions of CO_2 measured in kt generally showed an upward movement with the exception of years 2000 and 2005. With 3344kt emission in 1989, CO_2 emissions increased till 1999 where it dropped from 6549kt to 6288kt in 2000, after which it increased till 2004 (to 7275kt) and dropped to 6956kt in 2005. It increased to 9578kt in the year 2007 (WDI, 2012). The emission of CO_2 in Ghana is about 0.05% of the total global emissions and it places 108th in the world. It represents a total per capita emission of nearly 1MtCO_2e per person as at 2006 (EPA, 2011). The Energy sector contributes the largest to emissions in the country accounting for about 41% of the nation's emissions between the years 1990 and 2006. This is followed by the agricultural sector contributing about 38% of the emissions (EPA, 2011).

There has been a surge in the concern of growing economic openness and its dangerous effects on the environment. Increased opportunities in trading and the related development of prospective pollution havens have added fears to the environment (Beghin et al., 1994). As a result of the environmental degradation potential of industrialization, human activities and trade, the government of Ghana established the Environmental Protection Agency (EPA) under the Environmental Protection Act, 1994 (Act 490) to regulate issues concerning the environment and its sanity. However, some researchers are of the view that environmental policies increase the cost of production and limits the trade competitiveness of countries engaged in such policies (see Mcguire, 1982). According to Lucas et al. (1992), the intensity of pollution is high in poor (low income) countries where environmental standards and regulations are low. These nations therefore tend to engage more in pollution intensive activities.

Production and consumption which are the starting and final result of trade are most likely to cause negative externality like pollution. As a result of this, Pigou (1920) suggested the use of taxes to coerce firms to internalize the environmental cost of pollution as part of their cost of production. According to Beghin et al., (1994), tackling externality caused by production with tax on output which is the same for those causing the pollution is not efficient because it leads to the reduction of output for all producers regardless of the amount of pollution caused. Beghin et al. (1994) also argues that an optimal policy shall be an even tax per unit of pollution as this will dissuade the causing of pollution. According to Mukhopadhyay and Chakraborty (2005) consumption in a nation causes GHG emissions in other nations as a result of international trade. As a result of trade, a nation's consumption might be the production of another nation's production, and the production of these goods causes pollution in the producer nation. Zhang (2011) shows that carbon emissions incorporated in the exports of China have rapidly increased since 1987. This implies that through international trade a chunk of China's carbon emissions have been consumed by other nations.

1.2 Problem Statement

The share of Africa's emission of global greenhouse gases will grow overtime as poverty is eliminated by social and economic development (Omojolaibi, 2009). The EPA (2011) has indicated that though Ghana's emissions are lower than other major developing economies, there is a high potential for it to increase overtime. A UN (2000) report indicates that global CO_2 emission has quadrupled in the last 50 years. Thus as the economy continues to grow and expand, dominated by agriculture, forestry, oil and trade there is also a high potential for pollution (CO_2) emissions to increase in Ghana.

Over the years, the emission of carbon dioxide in the country has shown an upward movement. In 2000, the total direct GHG emission in Ghana was estimated at 12.2MtCO_2e. This is 173% above 1990 levels of -16.8MtCO_2e and 96% lower than 2006 levels of 23.9MtCO_2e. This change amounted to 242.3% increase from 1990 to 2006 (EPA, 2011). The increase in trade associated with growing agriculture, extraction of minerals, drilling of oil, transportation and increased usage of energy put pressure on the environment in the form of pollution and increases the emissions of CO_2. The emissions of gases have the ability of increasing the earth's temperature, sea level, droughts and floods. Emissions of gases are directly related to global warming and this has adverse effect on the environment. With increasing economic growth and trade openness, Ghana is more likely to emit CO_2 and face harsher effects of global warming.

With the quest of the GIPC inviting foreign corporations to set up industries in the country coupled with the recent drilling of oil and also the yearning of the government for economic growth, the nation's potential of emitting gases (CO_2) is very likely to be high. The World Bank (1992) has estimated that Ghana's emission will be 4.4 million tonnes by 2025 and this indicates a sevenfold increase.

Works of Grossman and Krueger (1995) indicate that economic growth at its initial stage leads to environmental degradation but the environment improves as the nation attains per capita income of $8000. Holtz-Eakin and Selden (1995) infer a turning point of $35,418, Neumayer (2004) cites a range of between $55,000 and $90,000, Panayotou (1993) $3137 and Stern and Common (2001) $101,166. If these are true, then there is a high potential for environmental degradation increasing in Ghana since its per capita income is nowhere near these benchmarks.

This study therefore seeks to investigate and establish the effect trade openness and economic growth have on the emissions of CO_2. It also seeks to fill the literature gap currently existing. To the best of author's knowledge, there is no work done solely on the effect trade openness and economic growth have on CO_2 emissions in Ghana. Albeit very limited literature on Ghana and other countries in a panel data analysis do exist (see Adom et al. 2012, Narayan and Narayan, 2010 and Lopez, 1997).

1.3 Objectives of the Study

The objective of this study is to examine the causal linkages among trade openness, economic growth and carbon dioxide emissions in Ghana using time series econometric techniques. Specifically, the study seeks to achieve the following objectives:

i. Effects of trade openness and economic growth on carbon dioxide (CO_2) emissions in Ghana between 1971 and 2009

ii. To examine the effect of other variables like energy consumption and urbanization on CO_2 emissions

iii. To investigate the causal relationship between CO_2 emissions and economic growth

iv. To test the existence of the Environmental Kuznets Curve for Ghana

1.4 Hypothesis of the Study

The study postulates that;

i. Trade does not have significant impact on CO_2 emissions

ii. Economic growth does not have significant impact on CO_2 emissions

1.5 Justification of the Study

According to Adom et al., (2012), Africa has been recognized as an attractive place for the rest of the world. This is because the continent is seen to be full of unexploited opportunities in trade and also yearns to grow. They add that as African countries seek to grow, caution must be adhered to on the probable effect this growth will have on the environment, climate and human adaptation. The argument of the pollution haven hypothesis is that dirty industries in advanced countries where there are strict environmental regulations move to developing countries where rules governing the environment are relaxed or not very strict. As a result of the inception of the GIPC and the increasing quest by the government for trade to increase between Ghana and other countries, there may be likely adverse consequences on the environment. These activities coupled with the increasing trend of emission of gases (EPA, 2011) especially CO_2 are likely to negatively affect the environment as climate change sets in. Countries adversely affected by climate change are usually the poor (developing) countries that fall short in terms of financial, human and the infrastructural capacity to deal with it (Costello et al., 2009).

This study is imperative because it will inform us of the impact trade and economic growth have on the emissions of CO_2. CO_2 emission is harmful to the environment as a result of its contribution to global warming and climate change. Azomahou et al. (2006) point out that, the study of CO_2 and economic growth is of great concern and imperative for the following reasons;

GHG effect is noted to be a great danger to the wellbeing of the environment and of these GHGs, CO_2 is the most problematic and arduous to manage. Also, CO_2 is produced as a result of the consumption of fossil fuels which is a very important aspect of recent production and consumption. This work will enable policy makers to judge the response of the environment to trade and economic growth.

It is also relevant to study CO_2 emissions because of the crucial role they play in the recent debate on environmental protection and development since they contribute largest to global warming (Azomahou et al. (2006).

To the best of the author's knowledge, there is little or no evidence of an empirical work showing the connection among trade, CO_2 emissions and economic growth in Ghana. This paper will therefore act as part of a pioneering study for further studies.

1.6 Scope of the Study

The study aimed to find the effects trade openness and economic growth have on CO_2 emissions in Ghana. It includes theoretical and empirical discussions on trade, pollution (CO_2) emissions and economic growth. The study covers the period 1971 to 2009. The period is chosen due to its relevant and phenomenal coverage of economic programmes such as the economic recovery program (ERP), structural adjustment programme (SAP), economic and trade liberalizations. It is also chosen as a result of the availability of data of the choice variables.

1.7 Organization of the Study

The study is organized into five chapters. Chapter one deals with the introduction to the study, including the background, statement of problem, objectives, hypotheses, justification and scope of the study. Chapter two reviews both the theoretical and empirical literature on trade, pollution (CO_2 emissions) and economic growth. Chapter three and four cover the methodology used and data analysis respectively. The final chapter concludes the study with the summary of the findings, recommendations or policy implications and suggestions for future research.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the review of literature on trade, pollution (CO_2 emissions) and economic growth. The chapter is divided into four sections. The first section reviews the theoretical literature on trade, CO_2 emissions and economic growth. The second section deals with the review of empirical works related to the topic and the third deals with CO_2 and climate change and emissions of CO_2 in the world. Lastly, the fourth section deals with the overview of the Ghanaian economy, emissions of CO_2 in Ghana and climate change situation in the country.

2.2 Theoretical Review

This section reviews existing theories (literature) and theoretical works related to the topic.

2.2.1 The Environmental Kuznets Curve (EKC)

The Environmental Kuznets Curve (EKC) undoubtedly has become the fundamental economic theory underlying the relationship between economic growth and environmental degradation. The EKC is referred to as the hypothesis that the relationship between environmental degradation and per capita income (economic growth) demonstrates an inverted-U shape nature (Kijima et al. 2010).

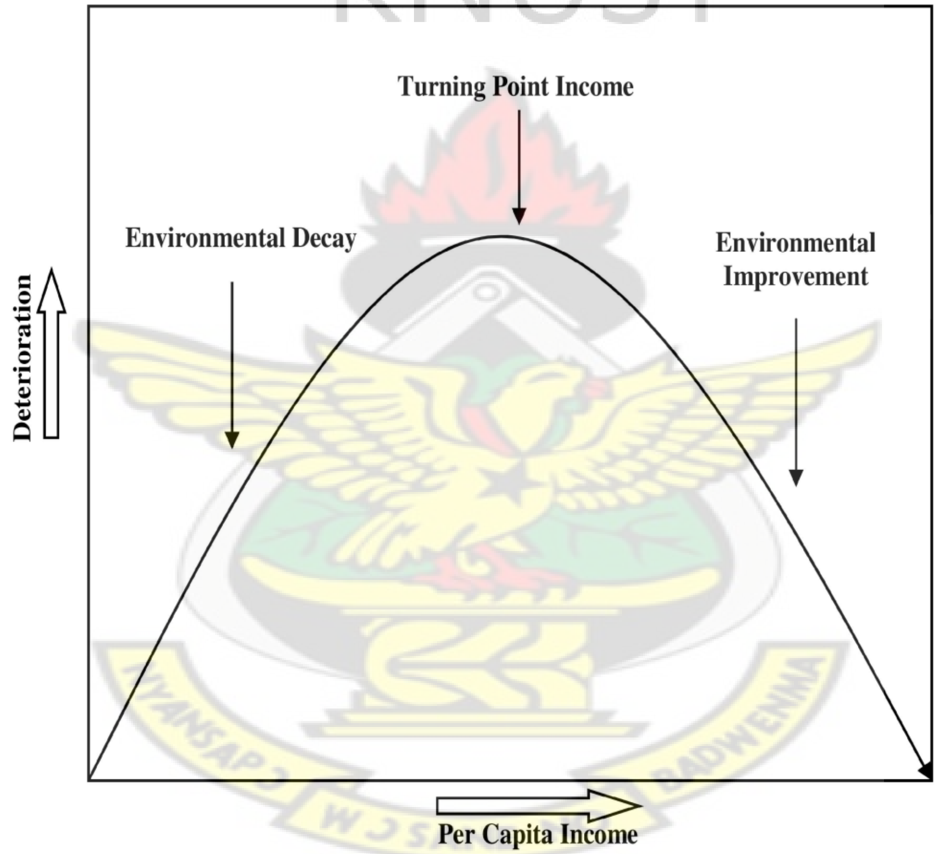
The EKC has its root from the Kuznets Curve as postulated by Simon Kuznets (1955). In his work entitled “Economic Growth and Income Inequality”, he suggested that there exists a U-shaped relationship between growth and income inequality. As per capita income increases, income inequality also increases, reaches a peak (turning point) and then starts to fall. Thus at the initial stages of growth, income inequality increases but as higher growth is attained, equality is also attained (Yandle et al., 2002).

The EKC was initiated by Grossman and Krueger (1991) in a work to investigate the environmental impacts of the North American Free Trade Agreement. Their work showed that as income (per capita) increase, environmental degradation (emissions) also increases but reaches a point and then starts to fall. This means that, as the economy grows emissions increase but as it further grows, environmental quality starts to improve.

They cite three channels with which this relationship between growth and the environment is portrayed. Firstly; in the initial stages of growth coupled with increased need for natural resources and waste generation, environmental degradation rises. They call this process the scale effect. Secondly; the growth might cause changes in the economic structure and move countries toward less polluting activities. This process is also known as the composition effect. Lastly; with increasing growth of the economy and higher incomes attained, countries will face technological substitution by moving toward less polluting processes. This is known as the technical effect. The scale effect represents the rising portion of the curve where environmental degradation increases with growth and the composition and technical effects represent the turning and decreasing portion of the curve. As income increases the living standards of people improve and tend to care more for the quality of their environment and call for better regulations of the environment. This tends to reduce the rate at which the environment is being degraded (Dinda, 2004). Poor people have lesser demand for clean environment.

This suggests that as an economy starts to develop, coupled with increased trade and industrialization, environmental quality is negatively affected but as it continues to develop, improvement in environmental quality is attained. This gives an inverted U-shaped nature or relationship between economic growth and environmental degradation. This U-shaped relationship between per capita income and environmental degradation is depicted in Figure 2.1.

Figure 2. 1 The Environmental Kuznets Curve



As per capita income increases deterioration of the environment increases, reaches a turning point and then starts to improve.

The issue of income level at which the turning point is attained has become questionable among economists and researchers. Thus, at what stage of development or level of per capita income does the environment start to improve? Grossman and Krueger (1995) suggest a per capita income of $8000. Holtz-Eakin and Selden (1995) infer a turning point of $35,418 whilst Neumayer (2004) cites a range of between $55,000 and $90,000. Cole (2004) got a turning point of $62,700 when he used a log-linear model and $25,100 with a levels model for the USA. The EKC portrays a long-run phenomenon (Dinda, 2004).

In recent periods a considerable number of researchers have been concerned about and written largely on the EKC to analyze the relationship existing between pollution (environmental degradation) and economic growth and also the validity of the assertion of the EKC. Some works have shown results confirming the EKC hypothesis while others have defied it.

The first empirical work on the EKC was done by Grossman and Krueger (1991) and found an inverted "U"-shaped relationship between pollutants and economic growth in the USA. The following are some works and results on the EKC:

Orubu and Omotor (2011) in determining the relationship between per capita income and environmental degradation, found that suspended particulate matter conform with the EKC hypothesis but organic water pollutants do not (they showed an upward sloping relationship) in Africa. The results of Franklin and Ruth (2012) for USA over a period of 200 years showed a continued upward trend in per capita CO_2 emission with economic growth. Ahmed and Long (2012) found results that conform to the EKC between CO_2 and growth in Pakistan between 1971 and 2008. Song et al. (2012) testing the existence of the EKC for 30 provinces and cities in China found that EKC does not hold for some provinces and for others they had reached their turning points. Iwata et al. (2010) provide results supporting the assertion of the EKC hypothesis with CO_2 emissions by taking into account nuclear energy in the production of electricity in

France. Roca and Alcantara (2001), in examining the relationship between growth and CO_2 emissions rejected the existence of the EKC in Spain from 1972 to 1997. Akbostance et al. (2009) using time series CO_2 emissions and per capita income from 1968 to 2003 and panel data from 1992 to 2001 with other 58 provinces found no evidence for the EKC among $PM_{10,}$ SO_2 and per capita income. Song et al. (2008) found an inverted U-shaped relationship between pollutants (waste gas, waste water and solid waste) and economic growth from 1985 to 2005 in China. He and Richard (2010) found little evidence in favour of the EKC hypothesis in Canada for CO_2 emissions. Giovanis (2013) using micro data from Britain investigated the relationship between air pollutants (O_3, SO_2 and NO_x), personal and household income from 1991 to 2009. Using fixed effects model, the paper found no evidence for the EKC, however it found strong evidence for EKC when using dynamic panel data and Bond GMM and logit models.

Others like Narayan and Nayaran (2010), Kaufmann et al. (1998), Schmalensee et al. (1998) and Grossman and Krueger (1995) showed results that affirm the assertion of the EKC while others like Hettige et al. (2000) and Jaunky (2011) gave results showing otherwise

The empirical works above show that the argument of the EKC hypothesis is inconclusive. Some researchers are of the view that varied conclusions would be made about the EKC as a result of differences in methodology, time period, specific country and the kind of countries in a panel data used (see Grossman and Krueger, 1993; Selden and Song, 1994; Hill and Magnani, 2002).

2.2.2 The Pollution Haven Hypothesis (PHH)

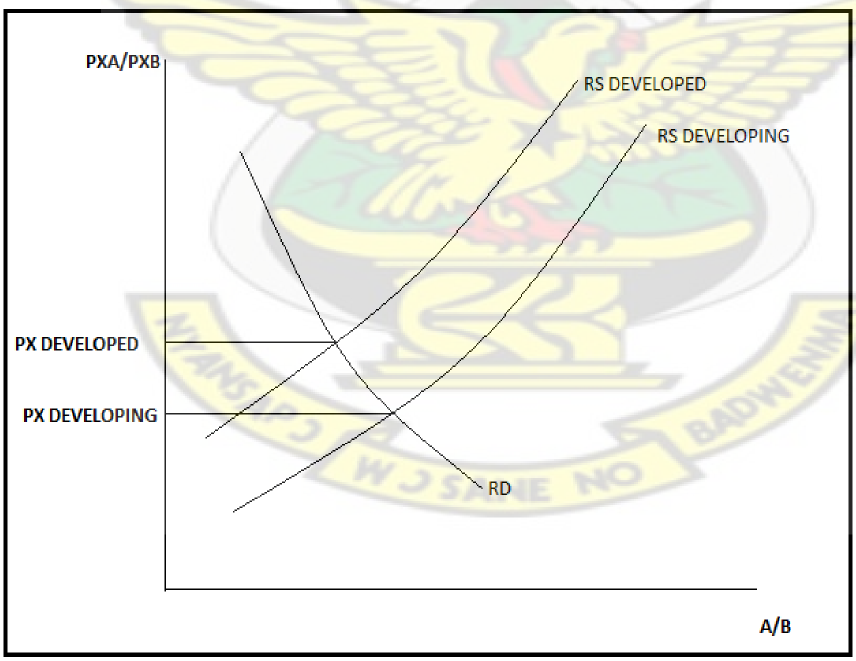
The PHH states that regulations of the environment will move polluting activities of tradable commodities to poorer countries (Eskeland and Harrison, 2003). It predicts that with globalization and trade liberalization, multinational firms in advanced countries where environmental regulations are strict will shift the production of their pollution intensive commodities to regions where environmental regulations are laxer. It predicts that with trade MNC's from advanced countries will move the production of their products that are pollution intensive to developing countries where there are poor environmental regulations. As time goes on the developing country will have comparative advantage in the production of these dirty goods (pollution-intensive goods) since their economies support their production. With this the developed countries benefit from environmental quality at the expense of the developing countries (Temurshoev, 2006). This will increase the pace of the emission of pollutants in the developing world and cause its countries to be dirty. The hypothesis argues that because environmental regulations in the developed countries are stricter than in the developing countries, corporations engaged in the production of dirty products move to developing countries increasing the pace of pollution (emissions) there. Pollution is therefore imported from developed countries to developing countries.

According to Temurshoev (2006), developing countries have relaxed environmental regulations or policies because; the cost involved in the promulgation, implementation and the monitoring of environmental policies are comparatively higher. Also the attention of developing countries is much on increasing earnings and jobs rather than pollution and health related matters relative to developed countries. Lastly, growth in developing countries indicates a passage from agrarian to industry. This increases the rate of urbanization and coupled with increased investment in urban infrastructure, pollution (emissions) increases.

2.2.2.1 Illustrating the PHH

Supposing there are two nations; the developed nation and the developing nation. Both nations produce two goods, good *A* and good *B*. Assume the production of good *A* is pollution intensive (that is, generates more pollution in its production) thereby becoming a dirty good and *B* is a clean good (does not generate pollution in its production). The nations are identical with the exception of the developed having a greater income. Assume further that; the developed nation is more productive in the production of both goods, the goods have the same preferences, are homothetic and separable from environmental quality. The diagram below shows the relative demand and supply of good A.

Figure 2. 2 Illustration of the PHH



From the diagram, *RD*, *RS DEVELOPED*, *RS DEVELOPING*, *PX DEVELOPED*, *PX DEVELOPING* and *PXA/PXB* denote relative demand for good *A* for both nations, relative supply of good *A* in the developed nation, the relative supply of good *A* in the developing nation, price of *A* in the developed nation, price of A in the developing nation and relative price of *A* and *B* respectively.

As a result of the assumption of homotheticity, the relative demand curves of both good A and B are the same for both countries. The relative supply curve is also identical for both nations in the absence of environmental (pollution) policy. At this point no country enjoys comparative advantage.

Supposing government is introduced in both countries and they come up with policies to check the degradation of the environment in both nations. The developed nation has a greater income than the developing as a result of its advanced productivity. In effect, the developed nation will adopt and implement a stricter environmental policy. This causes the relative price of polluting to rise in the developed nation. The cost of producing good *A* which is dirty will therefore be higher in the developed nation. This implies that the relative supply curve of the developed nation will be higher (on top) than that of the developing nation.

In autarky, the relative price of *A* will be higher in the developed nation than the developing nation. This is shown in the diagram as *PX DEVELOPED*. This suggests that with the coming in of trade openness, the developed nation will have a comparative advantage in the production of good *B*, the clean good since it will be relatively cheaper to produce than *A*. The developing nation will have comparative advantage in the production of good *A*, the dirty good as a result of its lax or weak environmental regulations and policies. It will be relatively cheaper polluting in the developing nation. The developing nation then becomes a pollution haven for the production of the dirty good. Industries in the developed nations engaged in the production of good *A* will then move to the developing nation since it will be cheaper to produce there. The developed nation specializes in the production of the clean good (*B*) and the developing nation, the dirty good (*A*). Industries in the developed nations engaged in the production of good A will then move to the developing nation since it will be cheaper to produce there (Copeland, 2005).

Evidence on the assertion of the PHH have produced mixed findings and till now have not been very conclusive. Some studies have produced results supporting it and others defying it.

Below are a number of studies on the PHH; Dean (2009) using 2,889 manufacturing equity joints venture projects in China from 1993 to 1996 found evidence supporting the PHH by foreign investors in China but not from investors from high income countries. Mani and Wheeler (1997) using data from 1960 to 1995 between OECD (particularly Japan) and developing economies (Asia and Latin America) found evidence for the PHH. Cave and Blomquist (2008) in their study found evidence for PHH with EU energy intensive trade but found no evidence supporting toxic intensive trade with poorer OECD economies and non- EU European countries from 1970 to 1999. Jie He (2006) studied the PHH using 29 provinces in China and found out that a 1% increase in FDI led to 0.098% increase in pollution (SO_2). Cole (2004) found little evidence for the PHH using four developed and developing trade pairs namely; USA-Asia, USA-Latin America, UK-Asia and Japan-Asia between 1977 and 1995.

Eskeland and Harrison (2003) in testing the authenticity of the PHH for four developing countries ((Mexico (1990), Venezuela (1983-1988), Morocco (1985-1990) and Cote d'Ivoire (1977-1987)) and USA (as the developed country) found no strong evidence for the PHH. Letchumanan and Kodama (2000) in testing the validity of the PHH between developing (Malaysia, Singapore, Thailand, The Philippines) and developed countries (USA, Germany, Japan) between 1978 and 1995 suggested that there is no strong empirical validation for the PHH. Instead they argued that trade and investment do lead to the movement of high technology and cleaner products and processes to developing countries which help them to improve upon their technology and also produce environmental responsive products. The Porter Hypothesis also argues that stringent environmental policies and regulations do not cause firms to move from places where they are very stringent to lax regions but rather persuade them to come up with cleaner (less pollution intensity) products and production processes (Porter and van der Linde, 1995).

2.2.3 Effect of Trade on Pollution for an Exporter of Dirty Goods

Following the work of Copeland (2005), the study presents a model involving the demand and supply of pollution emissions in Figure 2.3 to study the effects of trade openness on economic growth and the environment of a hypothetical nation. The model has the following assumptions;

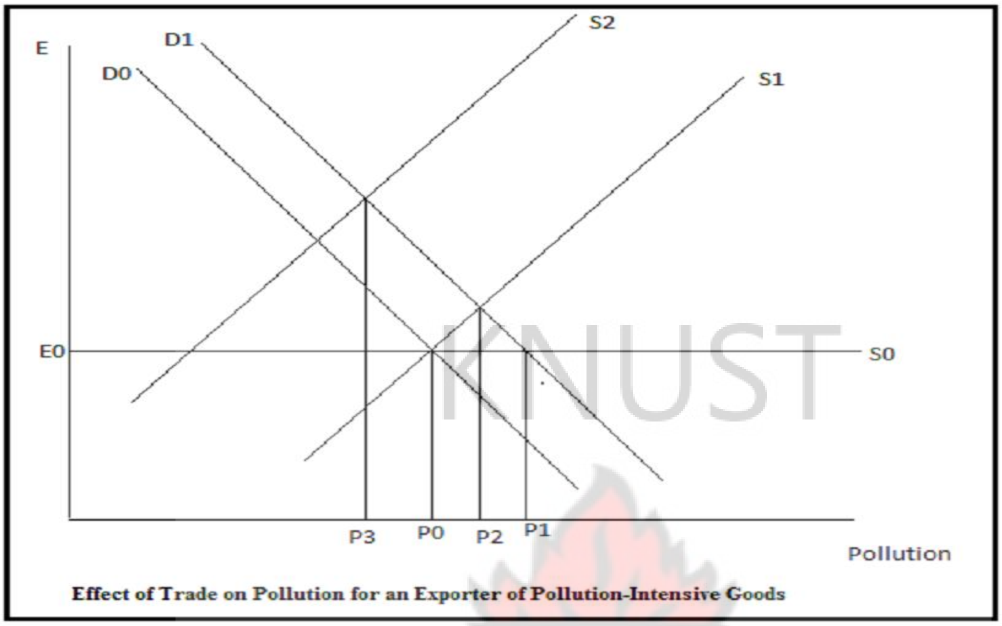
i. The nation understudy exports dirty commodity. A dirty commodity is a commodity whose production is considered to be pollution intensive.

ii. The nation pays a pollution emissions tax of *E* and this used as a measure of its strict environmental regulations.

iii. The demand for pollution (*D*) is derived. This makes pollution a side effect of production. The nation generates more pollution as the cost of environmental degradation (pollution tax, *E*) is low.

iv. The supply of pollution (*S*) shows the nation's eagerness to permit pollution as exhibited by the pollution (environmental) policy.

Figure 2. 3 Effect of Trade on Pollution for an Exporter of Pollution-Intensive Goods



Pollution is on the horizontal axis and pollution tax on the vertical axis as a proxy for the stringency of environmental policy. *P*, *E*, *S* and *D* represent the level of pollution, emissions or pollution tax, supply and demand respectively.

Supposing the nation has a fixed tax for pollution emissions, then the supply curve of pollution can be given by *S0* as shown in the diagram. The equilibrium values of pollution emissions tax (*E0*) and the level of pollution emissions (*P0*) are given by the intersection between the demand curve (*D0*) and supply curve (*S0*). In this situation, trade openness causes a rise in the export of dirty commodities and this effects a shift in the demand for pollution emissions to *D1*, hence causing pollution emissions to rise to *P1*.

Supposing the government of the nation makes environmental regulations stricter as a result of the rise in environmental degradation, the supply curve is then denoted by *S1*. With this, an outward shift in demand for pollution emissions as a result of trade leads to pollution *P2*. Consequently, the move of the government lessens the rise in emissions from *P1* to *P2*.

At last, consider that the pollution emissions curve is income-responsive. Because environmental quality is a normal good, the demand for environmental quality is expected to increase with income. Trade openness will normally cause a rise in income per capita. As income increases the demand for clean environment also increases. This suggests that the supply curve of pollution emissions will shift leftward to *S2* if the government is receptive to consumer preferences and this leads to a decrease in pollution emissions to *P3* from trade openness despite the nation's comparative advantage in pollution intensive commodities.

The amount by which the supply curve shifts back depends on income and substitution effects. With a sufficiently strong income effect, the new supply curve will be *S2*, leading to a fall in pollution from trade liberalization despite the country having comparative advantage in the dirty goods.

2.2.4 Pollution in a Small Open Economy

Supposing there are two industries in a market economy; industry *M* producing a dirty good *A* and industry *N* producing clean good *B*. Both goods are produced with constant returns to scale technology.

It is assumed that there are two factors of production capital (*K*) and labour (*L*) with marginal returns r and ϖ respectively. Both *K* and *L* have inelastic supply. Government factor is relevant for regulatory purposes since pollution levels are likely to be high in a market economy. Good *A* generates pollution during production but *B* does not.

Let good *B* be the numeraire so that the price of *B* is equal to 1 (P_B =1) and the domestic relative price of *A* be *P*. Assume further that good *A* is capital intensive and it represents the polluting sector. This is in line with industrial pollution. *B* is labour intensive. This means that for any *r* and ϖ the ratio K/L in *A* is greater than *B*;

$\frac{K_a}{L_a} > \frac{K_b}{L_b}$ ……. (1)

The production function for good *B* can be expressed as below;

$b = H(K_b, L_b)$…………. (2). It is assumed that *H* is increasing and strictly concave in inputs.

Industry *M* which is the polluting industry jointly produces two outputs (goods), good *A* and pollution emissions *C*. Industry *M* generates pollution however abatement is permitted. Supposing industry *I* can apportion a proportion ϕ of its inputs to abatement activity. A rise in ϕ implies a reduction in pollution but at the expense of good *A* since resources are diverted to abate *C*. The joint production technology is given by;

$a = (1 - \phi)F(K_a, L_a)$……….. (3)

$c = \delta(\phi)F(K_a, L_a)$……………. (4)

Where *F*, is increasing, concave and linearly homogenous.

$0 \leq \phi \leq 1, \delta(0) = 1, \delta(1) = 0$ and $d\delta/d\phi < 0$.

If $\phi = 0$, abatement is zero. There is no abatement and each unit of output generates one unit of pollution. If this happens, $F(K_a, L_a)$ can be taken as the potential output.

$a = F(K_a, L_a)$…… (5)

$c = a$……….. (6)

However if $\phi > 0$, then some resources of production are allocated to abatement. If a vector of (K_a, L_a) is allocated to the good A industry, then it can be said that ϕK_a and ϕL_a units of capital and labour respectively are apportioned to abatement activities. It can be implied that the industry produces a potential output of $F(K_a, L_a)$ and using a proportion ϕ of this as a factor for abatement.

The net output of the industry becomes;

$$(1 - \phi)F(K_a, L_a)$$

This is what is left for consumption in the domestic economy and also for export. From equation (4), the following functional form of abatement is adopted;

$\delta(\phi) = (1 - \phi)^{1/x}$…………… (7). Where $0 < x < 1$

Combining equations (3), (4) and (7), the term ϕ can be eliminated. The joint production technology can be inverted to obtain;

$a = c^x [F(K_a, L_a)]^{1-x}$…………… (8)

This is valid for $C \leq F$, because $\phi \geq 0$. That is, pollution can be treated as an input though it is a joint output.

Abatement is like any other activity the good *A* industry (*M*) undertakes. The amount of quantity abated is dependent on the amount of resources allotted to abatement which can be denoted by a^X and the amount of pollution potentially produced, c^P. Abatement technology is expressed as

$X(c^P, a^X)$ where X exhibits constant returns to scale. Pollution emissions are the difference between potential emissions and abatement;

$c = c^P - X(c^P, a^X)$………. (9).

Because abatement is a constant returns to scale activity, equation (9) can be re-expressed as

$c = c^P[1 - X\left(1, \frac{a^X}{c^P}\right)]$…….. (10).

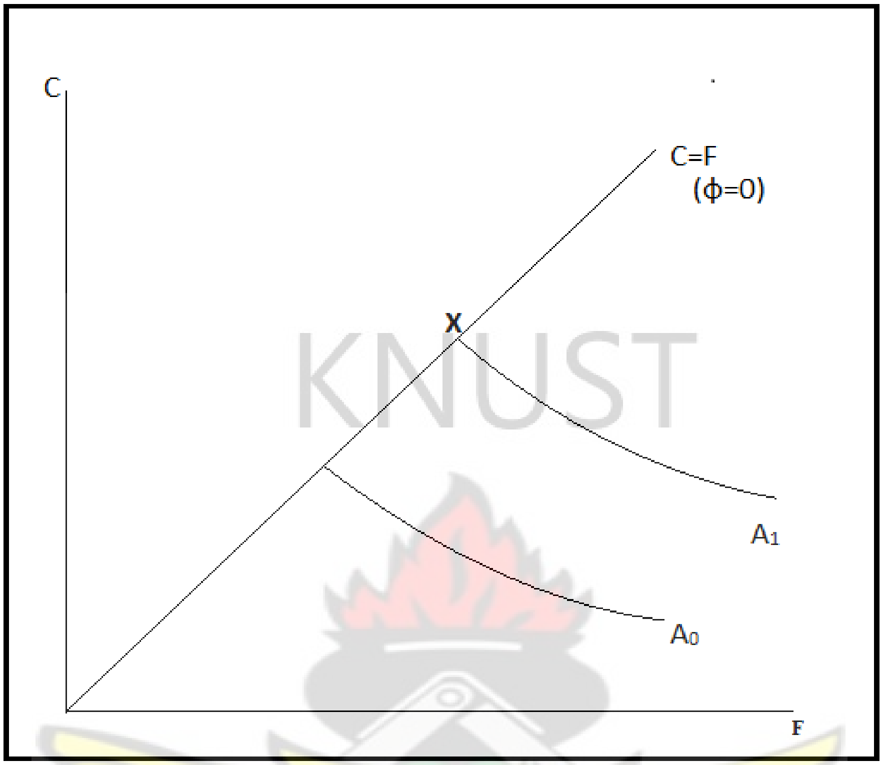
Referring to equation (6), $c = a$, potential pollution is equal to potential output. Therefore $c^P = F$ and ϕ is the proportion of resources allotted to abatement. This implies that $\phi = \frac{a^X}{F} = a^X/c^P$. Equation (10) can therefore be expressed as;

$c = [1 - X(1, \phi)]F(K_a, L_a) = \delta(\phi)F(K_a, L_a)$ where $\delta(\phi)$ is expressed as

$\delta(\phi) = 1 - X(1, \phi)$.

The relationship among net output, potential output and the resources allotted to abatement can be expressed in Figure 2. 4 using isoquants.

Figure 2. 5 Isoquants for the good A industry (M)



The diagram depicts isoquants for two levels of net output in the good *A* sector. The higher isoquant A_1 means a higher output. An isoquant illustrates the tradeoff between factors of potential output denoted by *F* and pollution emissions, *C* for a constant amount of net output.

At point *X* on the isoquant for A_1, no abatement is undertaken and pollution is proportional to output. This means $\phi = 0$ in equations (3) and (4). Other points on the line from the origin correspond to no abatement points on the isoquants. As we move down along an isoquant, pollution emissions decline because the industry has allotted resources to abatement. To have a constant level of net output, the factors of production into production as measured by *F* must increase as the level of pollution declines (Copeland and Taylor, 2003).

2.3 Empirical Review

Narayan and Narayan (2010) in their work used panel co-integration to determine the relationship existing between CO_2 emissions and economic growth for 43 developing countries from 1980 to 2004. Their work indicated that for Iraq, Jordan, Kuwait, Yemen, Qatar, the UAE, Argentina, Mexico, Venezuela, Algeria, Kenya, Nigeria, Congo, Ghana and South Africa which formed about 35% of the countries used, CO_2 emissions had declined overtime. In these countries income have contributed to less CO_2 emissions in the long run. However its impact was positive. Results from the South Asian and the Middle Eastern countries also showed that CO_2 emissions were lower in the long-run compared to the short-run.

By employing the use of a multivariate Vector Error Correction Model (VECM) methodology, Akpan and Akpan (2012) investigated the long-run and the causal connections among electricity consumption, carbon emissions and economic growth in Nigeria. They used annual times series data from 1970 to 2008. The study found out that in the long-run there existed a positive relationship between economic growth carbon emissions. However, it found a negative relationship between electricity consumption and carbon emissions. They blamed this negative relationship on the large deficit and excess demand for electricity in Nigeria. An increase in economic growth and electricity led to an increase in the emissions of carbon. The results of the Granger Causality test showed a unidirectional causality running from economic growth to carbon emissions with no reverse causality.

Jayanthakumaran et al. (2012) used bounds test approach to co-integration and the ARDL methodology to make a comparative analysis of CO_2 emissions, energy consumption, trade and income in China and India between the periods of 1971 and 2007. China and India were chosen by them because they are the two largest transitional and growing economies in the world. They however indicated that, despite these similarities between them they are not the same when it comes to structural changes in growth, trade and energy usage. Their work showed evidence for the EKC for the two countries. For China; if per capita income increased by 1%, it led to 1.62% increase in CO_2 emissions. For India; the long-run elasticities for per capita income and per capita income squared were 7.85% and -0.66% respectively. The results also show that there exists a negative relationship between trade and CO_2 emissions in the short run. A 1% increase in trade openness would decrease CO_2 emissions by 0.08%.

Sharma (2011) in his work attempted to investigate the determinants of CO_2 emissions for 69 countries between the period 1985 and 2005 using a dynamic panel data. He subdivided the countries into high, middle and low income. The high income consisted of 28 countries, the middle income 27 and the low income 14. The variables used were CO_2 emissions, trade openness, urbanization, GDP and energy consumption. The paper found out that GDP per capita and urbanization were the two main determinants of CO_2 emissions in the global panel (all countries combined). Trade openness, per capita total primary energy consumption and per capita electric power consumption had statistically insignificant effect on CO_2 emissions. GDP per capita had a statistically significant positive effect on CO_2 emissions for the global, middle and low income panels. It had a statistically insignificant effect for the high income panel however positive. Trade openness was statistically insignificant on CO_2 emissions in all the panels. Urbanization had a statistically significant negative effect in the global panel. The energy variables had a positive effect on CO_2 emissions in all the three income panels.

Sanchez-Choliz and Duarte (2004) did a work to analyze the sectoral impacts that Spanish international trade relations had on the emissions of CO_2 using input-output model and the concept of vertical integration. They used the Spanish input-output tables for 1995 and the

Satellite Atmospheric Accounts for 1997. Their results showed that total pollution measured in the amount of CO_2 emissions in the final demand was higher in all cases than home produced pollution. Out of 322,394 thousand tonnes of CO_2 emitted from Spanish final demand, 206,514 thousand tonnes (64%) was as a result of national production processes and 115, 880 thousand tonnes (36%) was generated from abroad. 89,992 thousand tonnes of the imported pollution was as a result of inputs and 25,883 thousand as a result of consumption goods. The production of exports generates 120,117 thousand tonnes of CO_2 emissions representing 37% of total CO_2 emissions in the country. The CO_2 emissions in Spain were mainly as a result of national production processes that produce both for home and foreign markets. However, large quantities of CO_2 are also imported through the process of meeting its national consumption demand.

Yunfeng and Laike (2010) did a work to estimate the amount of CO_2 emitted as a result of China's foreign trade between 1997 and 2007. They used the input-output approach. Their work showed that 10.3% to 26.54% of China's yearly CO_2 emissions are produced as a result of goods manufactured for export while those emitted as results of imports accounted for 4.40% in 1997 and 9.05% in 2007. During the period 1997 to 2007, the net additional worldwide CO_2 emission coming out of China's trade was 1132.02Mt. In decomposing the effects of CO_2 emissions; the growth in China's export (scale effect) caused its entire emissions to increase by 1413.15Mt (450%). The changes in export structure (composition effect) accounted for an extra 147.40Mt (47%) increase. However, the improvement of emissions (technical effect) caused CO_2 emissions to fall by 149.77Mt (48%). In relations to imports, CO_2 emissions had increased by 327%, 29% and 58% on the basis of scale, composition and technical effects respectively. The results showed that trade contributed significantly to the emissions of CO_2 in China.

In 2009, Halicioglu used the Bounds Testing to co-integration procedure to examine the dynamic causal relationship between CO_2 emission, energy consumption, trade and income for Turkey between the years 1960 and 2005. The work suggested that income is the most significant variable explaining CO_2 emissions, followed by energy consumption and then trade.

The work of Al-Mulali (2012) investigated the major factors that influenced the emissions of CO_2 in 12 Middle East countries namely; Bahrain, Egypt, Iran, Jordan, Kuwait, Lebanon, Oman, Qatar, Saudi Arabia, Syria, the UAE and Yemen for the period 1990 to 2009 using panel model. The results of the work showed that energy consumption, FDI net inflows, GDP and trade were very relevant factors in increasing the emissions of CO_2 in the long-run for the countries mentioned afore. The work showed that a 1% increase in total primary energy consumption, FDI net inflows, GDP and total trade would increase CO_2 emissions by 3.49%, 4.85%, 20.08% and 2.33% respectively.

Wang (2012) using Dynamic Threshold Panel Model between 1971 and 2007 for 98 countries investigated the existence of threshold effect in the relationship between oil CO_2 emissions and economic growth. The study wanted to find out whether different levels of economic growth in these countries had different effects on the emissions of CO_2. The cointegration results indicated that in the long term, the relationship between oil CO_2 emissions and economic growth was strong. In the low economic growth periods, there was a negative relationship between economic growth and the growth rate of oil CO_2 emissions. In the medium economic growth period, economic growth had a significantly positive relationship between growth and oil CO_2 emissions. Lastly, in periods of high income (economic growth), the relationship was insignificant. In concluding, the work suggested per capita GDP has a positive impact on the emission of oil CO_2.

In 2007, Wu et al. used input-output structural decomposition analysis to investigate the effect of trade transformation on the emissions of CO_2 in Taiwan between the periods 1989 to 2001. The results showed that the change in the level of export caused industrial CO_2 emissions to increase by 72.1% during the 1989 and 2001 period. Changes in export mix caused CO_2 emissions to fall by 5.7% and changes in the import coefficient caused CO_2 emissions to fall by 11.7%. The change in export mix is the comparative advantage between Taiwan and China and ASEAN countries toward technology-intensive industries.

Saboori et al. (2012) examined the relationship between economic growth and CO_2 emissions in Malaysia between the period 1980 and 2009 using the ARDL model. The results showed a strong long-run relationship between CO_2 emissions (per capita) and GDP (per capita) when CO_2 emissions are treated as the dependent variable. An inverted "U" shaped relationship between economic growth and CO_2 emissions was attained between the period in question, confirming the existence of the EKC hypothesis in Malaysia in both the short-run and long-run.

Azomahou et al. (2006) investigated the relationship existing between CO_2 emissions and GDP (as a proxy for economic development) for the period 1960 to 1996 for 100 countries using Poolablity test of Baltagi et al. (1996). Their results showed an upward sloping relationship between CO_2 emissions and per capita GDP for the 100 countries. This meant there was a positive relationship between CO_2 emissions and economic development; as the economy grew, CO_2 emissions increased. This finding goes contrary to the EKC hypothesis which depicts a "U" shaped relationship between these variables.

In 2003, Friedl and Getzner examined the relationship between economic development (using GDP growth as a proxy) and CO_2 emissions in Austria for the period 1960 to 1999 based on the

EKC hypothesis. In investigating the time series of CO_2 emissions the authors divided the period into two; the period before the oil shocks in the mid 1970's and the period 1975 to 1999. The first period showed a comparative increase in CO_2 emissions with economic growth and the second showed a notably smaller growth of CO_2 emissions. The relationship between CO_2 emissions and economic growth depicted an "N"-shaped relationship. The authors cited that, this outcome may be as a result of; mere statistical result and also since prices of oil are not experiencing permanent surge lately, the force to increase energy efficiency and to come out with strict environmental policies is steadily declining. They found out that the main determinant of CO_2 emissions in Austria is economic growth.

Menyah and Wolde-Rufael (2010), investigated the long-run and causal relationship among economic growth, pollutant (CO_2) emissions and energy consumption in South Africa from 1965 to 2006 using the Bounds Test Approach to co-integration. The results showed a unidirectional causality running from CO_2 emissions to economic growth, from energy consumption to CO_2 emissions and from energy consumption to economic growth all without feedback. The results showed a positive long-run relationship between economic growth and CO_2 emissions, positive relationship between energy consumption and CO_2 emissions and a negative relationship between energy consumption and economic growth. These suggested that, a decline in CO_2 emissions could also lead to a decline in economic growth and a decline in energy usage would lead to a decline in CO_2 emissions. These outcomes suggested that economic growth is not a panacea for reducing CO_2 emissions since the reduction in CO_2 emissions may affect economic growth positively.

Naranpanawa (2011) using the ARDL model to investigate the linkage between trade openness and CO_2 emissions in Sri Lanka between the period 1960 and 2006 found out that there existed no long-run nor long term causality between them. But in the short run the study found a positive relationship between CO_2 emissions and trade openness. Therefore trade openness had not significantly contributed to the emissions of CO_2 in Sri Lanka.

2.4 CO_2 Emissions and Climate Change

Human activities in relation to production, consumption and energy usage worldwide are the causes of global climate change (Dhillon and von Wuehlisch, 2013). According to Rehan and Nehdi (2005), climate change is a long-term shift or alteration in the climate of a particular location, region or the entire planet. Human activities have increased the amount of GHGs in the atmosphere since the industrial revolution and this has led to an increase in the retention of heat in the atmosphere (WMO, 2012). Sunlight reaching the surface of the earth can return to space or be absorbed by the earth. When it is absorbed, the earth radiates some of the heat to the atmosphere. However GHGs like water vapour, CO_2 and methane act like a blockade slowing or blocking the loss of heat to space. This makes the earth warmer. This process is known as the greenhouse effect (US-EPA, 2012). The change in the earth's temperature is known as global warming (WMO, 2012). It comes about as a result of emission of GHGs into the atmosphere (Michaelis, 1993). Between 1750 and 2000, GHGs have increased by 31% and 151% respectively (VijayaVenkataRaman et al., 2011). This has in turn had effect on the climate of the world.

CO_2 is the primary greenhouse gas that is contributing to the recent climate change (US-EPA, 2012). The observed increasing global temperature since the mid 20th century is much likely to be the result of the rising emission of GHGs into the atmosphere by human activities (IPCC, 2007). Svante Arrhenius (1896) predicted that the burning of fossil fuels may increase the emission of CO_2 and have a warmer effect on the earth (Pittock, 2003). Increasing levels of CO_2 emitted into the atmosphere is vehemently believed to be the key source of human-induced climate change (Rehan and Nehdi, 2005; IPCC, 2007). CO_2 concentration in the atmosphere has increased to 360ppm in recent years from 280ppm since the industrial revolution (Stevens, 1994). Increased CO_2 emission is considered to be the cause for the warming of the earth's surface (Kessel, 2000). Activities of human presently discharge over 30 billion tonnes of CO_2 into the atmosphere every year (US-EPA, 2012). Sun and Wang (1996) using data from 1860 to 1988 found a very strong positive correlation between CO_2 emissions and climate change. It is mainly responsible for global warming.

CO_2 is a naturally occurring gas, a by-product of burning fossil fuels and biomass and as a result of land use changes and other industrial processes (Florides and Christodoulides, 2008). It is emitted due to the burning of coal, oil and gas, changing land use and deforestation (Sun and Wang, 1996). These activities reflect themselves in trade since trade involves transport and production which uses coal, oil, gas and land. Climate change results in harsh hurricanes, floods and drought which have unfavorable effect on productivity, agriculture and the society (IPCC, 2001). The recent heat waves, drought, floods and storms occurring in a number of countries around the world are all as a result of global warming and climate change. They cause sea levels to rise and this has the potential of increasing coastal erosion, loss of tourism, increased floods and likely loss of lives (Dhillon and von Wuehlisch, 2013). Costello et al., (2009) indicated that global warming will worsen the situation of drought, heat waves and increase the severity of floods and storms. It will also lead to food insecurity (the harvest of rice and maize is likely to fall between 20% and 40%), reduced water and these will have harsh effect on the health of billions (in relation to cardiovascular diseases, diarrhoea and malaria). They also added that with global warming premature death is expected to increase continually. It leads to short term death of especially those with cardiovascular or respiratory diseases. It leads to increase in asthma, malaria and increases the risk of infectious diseases (Kurane, 2010).

2.4.1 World emission of CO_2

The Table 2.1 shows the emission of CO_2 by the first 20 largest emitters in the world in 2009.

Table 2. 1 World Emissions of CO_2 (annual emissions in millions of tonnes)

Rank	Country	CO_2 Emissions	Percent of Global Total	Per Capita Tonnes
1	China	7710.5	25.4	5.83
2	US	5424.53	17.8	17.67
3	India	1602.12	5.27	1.38
4	Russia	1572.07	5.17	11.23
5	Japan	1097.96	3.61	8.64
6	Germany	765.56	2.52	9.3
7	Canada	540.97	1.78	16.5
8	South Korea	528.13	1.74	10.89
9	Iran	527.18	1.73	6.94
10	UK	519.94	1.71	8.35
11	Saudi Arabia	470	1.55	18.56
12	South Africa	450.44	1.48	9.18
13	Mexico	443.61	1.46	3.99

14	Brazil	420.16	1.38	2.11
15	Australia	417.68	1.37	19.64
16	Indonesia	413.29	1.36	1.72
17	Italy	407.87	1.34	7.01
18	France	396.65	1.3	6.3
19	Spain	329.86	1.08	7.13
20	Taiwan	290.88	0.95	12.66
	TOTAL	**24329.4**	**80**	

Source: International Energy Agency (2009) as cited in Dhillon and von Wuehlisch (2013).

The USA used to be the largest emitter of CO_2 but since 2006 its emissions have fallen by 430Mt representing 7.7%, (IEA, 2012). China leads the emissions in the world with annual emissions of 7710.5 million tonnes representing 25.4% of the world's total emissions. It produces a per capita CO_2 emission of 5.83. The USA now lags behind China by about 5424.53 million tonnes representing 17.8% of the world's total. In the first five is India which together with China are the largest two emerging economies in the world. India comes third with a yearly emission of 1602.12 million tonnes representing 5.27% of the world's emission. In Africa, South Africa takes the lead as the largest emitter and it is the only African country appearing among the first twenty largest emitters. It emits 450.44 million tonnes representing 1.48%. South Africa's emission accounted for 40% of Africa's emission in 2009. The only South American country within the first twenty is Brazil emitting 420.16 million tonnes. The twenty countries combined emitted 24,329.4 million tonnes out of the world's 30,398 million tonnes, representing 80% of total emissions.

Sectorally, electricity and heat generation topped the emission by emitting 41%, followed by transport, industry, residential and others (including; commercial services, agric, fishing and forestry) emitting 23%, 20%, 6% and 10% respectively in 2009 (IEA, 2011).

2.5 Overview of the Ghanaian Economy

In achieving independence in 1957, Ghana embarked on policies to produce substitutes of its imports (known as import substitution industrialization) and stringent trade policies. Before the liberalization of trade in the country, it experienced abysmal growth performance. In 1970 it achieved economic growth of 7.2%. Between 1978 and 1983 the yearly average GDP growth rate was -1.34%. In 1975 GDP growth rate was -4%. For several years the country achieved negative growth rates (1964, 1966, 1968, 1972, 1973, 1975, 1976 and 1979 through 1983). From 1984 to 2006, the GDP growth rate averaged between 3.9% and 4.5%. The country experienced these negative GDP growth rates as a result of its adoption of import substitution policies, political instabilities, trade restrictions (in the form of very high tariffs, quotas and other stern import restrictions) and fixing of exchange rates (Ayine, 2004). The control of exchange rate and the high tariffs lasted till 1982. These activities created exchange rate and BOP problems in the country. During 1970 to 1982 the share of the county's export in the world fell by 68%. This period saw a sharp decline in imports and its imports/GDP ratio. It fell from 18.5 to 3.3 and that of export/GDP ratio by 20.7 to 3.6.

The country also went through a period of high inflation during this period. In 1965 it was 26.4%. It fell in 1966, through 1969 and afterwards followed an upward trend. In 1976 it was 56.08%, 116.45% in 1977, 78.09% in 1978, 116.5% in 1981 and 122.87% in 1983 (WDI, 2012).

Following the abysmal performance of the economy, the government of Ghana with assistance from the World Bank and the IMF launched the ERP in 1983 (Rodrik, 1999) for a reform of the physical infrastructure, economic institutions and measures to decrease inflation through a combination of monetary and fiscal policies. With the economic reforms in 1983, the country has witnessed a significant measure of economic growth, fiscal improvement and real effective exchange rate stability (Aryeetey and Baah-Boateng, 2007). As part of the measures of the ERP, trade was liberalized in 1986. This was to open up the economy for competition to the local industries so as to boost their efficiency. The liberalization involved the removal of the stringent quantitative restrictions, lowering of tariffs and the adoption of liberalized foreign exchange (Ayine, 2004). In its initial stages, it emphasized on the correction of foreign exchange and trade distortions and later on the correction of structural and macroeconomic imbalances (Sakyi, 2011). Import licenses were abolished in 1989 and tariffs were drastically reduced. Average real GDP growth from 1990 and 2000 was 4.3% and 5.1% between 2000 and 2005 (Sakyi, 2011). The liberalization has seen a tremendous improvement in trade in the country.

Ghana has been engaged in trade since independence. As part of the adoption of the Economic Recovery Programme (ERP) in the 1980's, Ghana adopted the trade liberalization in 1986. With the inception of the trade liberalization, Ghana's trade with the rest of the world has generally increased. Both imports and exports have been positively impacted. The volume of imports rose from US$712.5 million in 1986 to US$1728.0 million in 1993. The volume of exports also increased from US$773.4 million in 1986 to US$1234.70 million in 1994, (WDI, 2012). The programme has also led to an increase in multinational corporations investing in the country (Frimpong and Oteng-Abayie, 2006).

2.5.1 CO_2 Emissions in Ghana

The most abundant greenhouse gas produced and emitted in Ghana is CO_2 (EPA, 2011). From 1989 to 2007, the emission of CO_2 measured in kt in Ghana has generally shown an upward trend with the exception of the years 2000, 2005 and 2007. With 3344kt emission in 1989, CO_2 emissions increased till 1999 where it dropped from 6549kt to 6288kt in 2000, after which it increased till 2004 (to 7275kt) and dropped to 6956kt in 2005. It increased to 9578kt in the year 2007 (WDI, 2012). The emission of CO_2 in Ghana is about 0.05% of the total global emissions and it places 108th in the world. It represents a total per capita emission of nearly 1MtCO_2e per person as of 2006 (EPA, 2011). The Energy sector contributes the largest to emissions in the country accounting for about 41% of the nation's emissions between the years 1990 and 2006. This is followed by the agricultural sector contributing about 38% of the emissions and the waste industry emitting 8% (EPA, 2011). Report by the IEA (2011) indicates Ghana emitted 1.7, 1.5 and 4.8 million tonnes of CO_2 from electricity and heat production, manufacturing industries and consumption and transport respectively in 2009. CO_2 per population was 0.38 tonnes in 2009 and this represents 109.1% increase from 1990.

In 2000, the total GHG emission in Ghana was estimated to be about 12.2MtCO_2e. These gases included CO_2, methane, nitrous oxide and perflurocarbons. It represents a 173% increase above the figure for 1990 of -16.8MtCO_2e and 96% below of that of 2006 emissions accounting for 23.9MtCO_2e. There has been a 242.3% increase between 1990 and 2006. CO_2 emissions accounted for -16.3Mt in 1990, 13.3Mt in 2000 and 22.9Mt in 2006 of the total GHGs emitted. CO_2 forms the largest portion of GHGs emitted in Ghana. It accounted for 44% of GHGs emitted in 2000. On the average, it accounted for 81.3% of the total GHGs between 1990 and 2006. In Ghana it is mainly emitted from energy, land and forestry usage and industrial processes. In 2000 the energy sector, land and forestry and industrial processes accounted for 55%, 37% and 14% of CO_2 emissions respectively. Projections of GHGs indicate that their emissions could increase from 7,278Gg to 118,405Gg between 1994 and 2020, rise to 234,135Gg by 2030 and 519,826Gg by 2050. The EPA indicates that though Ghana's emissions of CO_2 relative to other countries might be low, it has very high potential in the short to medium term to increase as the economy continues to expand highly especially in the agriculture, forestry, oil and gas sectors.

2.5.2 Climate Change in Ghana

There is strong evidence supporting the fact that changes in the climate of the earth are associated with the release of GHGs (EPA, 2011). Over the past 30 years temperature in Ghana has risen by 1^{o}C and projections show that there is a high possibility of temperature increasing between 1.7 ^{o}C and 2.04 ^{o}C by 2030. In the Northern Savannah, temperature is likely to rise to as high as 41 ^{o}C. A 20 year observed data by the EPA indicates that temperature is rising in all ecological zones and rainfalls have been reducing generally. There is a high probability of sea levels rising by an average of 0.3cm from 3.6cm by 2010 to 34.5cm in 2080.

Climate change has worsened the poverty situation in the country especially in the north where temperatures are already high. It has led to a lower agricultural productivity and periodic flooding in the country. It has also increased the pace of migration of the youth from the north to the south as a result of the low agricultural productivity that comes with climate change. The EPA (2011) also indicates that, it has a potential for; increasing pressure on water and reducing the potential for hydropower, reducing access to water, increasing the incidence of diseases, food insecurity, causing loss of biodiversity, soil fertility and land degradation. All these are as a result of the increasing pace of CO_2 emissions in the country and its effects on the environment (EPA, 2011).

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter discusses the methodology used in the study. It mainly includes the data type, specification of the model, explanation of variables, a priori expectation of signs, stationarity, cointegration and Granger Causality tests. Cointegration is carried out based on the Johansen and Juselius (1990) Cointegration method.

3.2 Data Type and Sources

The study employed the use of annual time series data from 1971 to 2009. This period is chosen due to its remarkableness to the country, it marks the nation's economic recovery program (ERP), structural adjustment programme (SAP), economic and trade liberalizations. It is also chosen as a result of the availability of data of the choice variables. The data used is sourced from the World Bank's World Development Indicators (2012). Sources of supporting information include published articles, journals, working papers and textbooks. Variables used in the study were carbon dioxide emissions per capita, real GDP per capita, real GDP per capita squared, energy consumption, trade openness and urbanization. The econometric software used for the analysis is Eviews 7.

3.3 Econometric Framework

3.3.1 Model Specification

The model for the study is specified based on the Environmental Kuznets Curve (EKC) hypothesis. EKC is a hypothesized relationship between various indicators of environmental degradation and income per capita (Stern, 2004). The EKC depicts an inverted U-shaped relationship between environmental degradation and income per capita.

Following Saboori et al., (2012), the EKC in its general form can be written as:

$$E = f(Y, Y^2, Z) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

E is an environmental indicator representing environmental degradation, Y is income (real GDP per capita) and Y^2 is income squared. The square portrays the quadratic nature of the curve of the EKC; an inverted U-shape (Wang, 2012). Z is a vector of control variables that may contribute to environmental degradation.

In this study, the vector of control variables has trade openness (TO), energy consumption (EC) and urbanization ($URBAN$) as its members. Thus;

$$Z = (TO\ EC\ URBAN) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Replacing the vector Z by its elements in equation (1) yields the function in equation (3).

$$E = f(Y, Y^2, TO, EC, URBAN) \ldots\ldots\ldots\ldots\ldots\ldots (3)$$

The study used per capita CO_2 emissions as a proxy for the environmental indicator (E), real GDP per capita for real income and annual urban population growth rate as a measure for urbanization. Real GDP per capita squared is represented by W. E can therefore be expressed as:

$$CO_2 = f(Y, W, TO, EC, URBAN) \ldots\ldots\ldots\ldots\ldots (4)$$

Equation (4) can be written in its multiplicative form as;

$$CO_2 = \beta_0 Y^{\beta_1} W^{\beta_2} TO^{\beta_3} EC^{\beta_4} URBAN^{\beta_5} e^{\mu} \ldots\ldots\ldots\ldots\ldots\ldots (5)$$

The explicit estimable econometric model in its logarithm form is formulated as follows:

$$ln(CO_2)_t = \beta_0 + \beta_1 lnY_t + \beta_2 lnW_t + \beta_3 ln\,TO_t + \beta_4 lnEC_t + \beta_5 ln(URBAN)_t + \mu_t \ldots.(6)$$

All variables are as explained above, μ denotes the error term, t time and ln natural logarithm. β_i represent the elasticity coefficients.

Equation (6) shows the long-run equilibrium relationship.

The model is expressed in a logarithm form because of the following;

i. In order to have the same unit for the various variables. The log form enables us to have the values of all variables in the same unit. Whiles variables such as per capita CO_2 emissions, energy consumption, trade openness are relatively small others such as GDP per capita and GDP per capita squared are larger.

ii. Its usage minimizes the scale of the variables to a twofold from a tenfold hence minimizing the hetereoskedasticity in the model (Gujarati, 2005).

3.3.2 Explanation and A Priori Expectation of Variables

The independent variables used in the study have been chosen from theoretical and empirical literature and have been identified to have significant impact on the emissions of CO_2.

CO_2 Emissions Per Capita (CO_2)

CO_2 is a naturally occurring gas, by-product of burning fossil fuels and biomass and as a result of land use changes and other industrial processes (Florides and Christodoulides, 2008). It is emitted due to the burning of coal, oil and gas, changing land use and deforestation (Sun and Wang, 1996). It includes those produced during the consumption of solid, liquid and gas fuels and gas flaring. The study measures CO_2 emissions as per capita CO_2 emissions in metric tonnes. This measure of CO_2 emissions has been used by a number of researchers (see; Song et al. (2008), Akbostanci et al. (2009), Sharma (2011) and Wang (2012)).

Real GDP Per Capita (*Y*)

GDP is the value of total output of goods and services produced within a given country in a particular period. GDP per capita is the value of GDP divided by the population of the country. The study uses real GDP per capita measured in constant 2000 US Dollars as a measure for real income. The following authors have used this measure in a related work; Azumahou (2006), Iwata et al., (2010), He (2010), Franklin and Ruth (2010).

Based on the argument of the EKC the sign of β_1 is expected to be positive. The EKC postulates that, as the economy grows (real GDP per capita increases), environmental degradation (using per capita CO_2 emissions as a proxy) increases, reaches a point and turns to improve. Therefore the coefficient (β_1) of Y (real GDP per capita) is expected to be positive. That is greater than zero. $\beta_1 > 0$.

Real GDP Per Capita Squared (*W*)

This is the square of the real GDP per capita and it has been used by Azomahou (2006), Iwata et al. (2010), Saboori (2012), Jayanthakumaran et al. (2012) in a related study.

Based on the EKC hypothesis the coefficient (β_2) of real GDP per capita squared (W) is expected to be negative in order to reflect the inverted U-shaped curve.

Trade Openness (*TO*)

Trade openness is defined in the study as the sum of total exports and imports of goods and services expressed as a percentage of GDP. (See Sharma (2011), Jayanthakumaran (2012) for same measure in a related work).

Following the argument of the Pollution Haven Hypothesis (PHH), dirty goods industries in developed countries with stringent environmental policies will move to developing countries with lax environmental policies. The sign of the coefficient (β_3) of trade openness (*TO*), is expected to have an ambiguous effect, that is positive or negative depending on the stage of development of the country. For developed countries, it is expected to be negative. This is because their dirty goods industries move to developing countries which have weak environmental policies and import from there. This drastically reduces the extent of pollution from production in the developed countries. However, for developing countries it is expected to be positive. This is because the dirty industries which move to the developing countries increase the extent to which pollution (CO_2) emissions increase. Negative sign for developed countries means that it will be less polluted and positive sign for developing countries means it will be more polluted. Therefore, $0<\beta_3<0$.

Energy Consumption (*EC*)

The study uses energy use per capita as a proxy for energy consumption. Energy use refers to use of primary energy, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport (WDI, 2012). Energy use is measured in kg per capita. *EC* has been used by others like He (2010), Wang (2012) and Jayanthakumaran et al. (2012) in a related work.

A higher level of energy consumption corresponds with greater economic activities. Energy consumption increases the scale of economic activities. An increase in economic activities stimulates the emissions of CO_2. The sign of the coefficient (β_4) of energy consumption (*EC*) is therefore expected to be positive. Therefore, $\beta_4 > 0$.

Urbanization (*URBAN*)

Urbanization is the physical growth of urban areas as a result of rural migration and even suburban concentration into cities, particularly the very largest ones (Wikipedia, 2013). It measures the rate at which people move from rural areas to cities for better jobs, life, health, education, entertainment, etc. This has caused cities' population to increase. The study uses annual urban population growth rate in percentage to measure urbanization. This variable has been used by Iwata et al. (2010), Sharma (2011), Hossain (2012) in a related work.

The increase in the urban growth rate put pressure on urban resources and the environment. The pressure on the environment increases the extent to which it is polluted. Urbanization is therefore expected to have positive relationship with the emissions of CO_2. Therefore, $\beta_5 > 0$.

3.4 Unit Root and Cointegration Tests

3.4.1 Unit Root Test (Stationarity Test)

The nonstationarity test is performed to scrutinize the time series properties of the individual variables used in the study. The purpose is to determine the order of integration of each individual series in the study in order to guide the choice of estimator. One underlying assumption of the ordinary least squares estimator is that the distribution of the data generating process is stationary. Hence application of this estimator in the presence of nonstationary regressors could lead to nonsensical inference and conclusions. It is therefore important to determine the order of integration of each variable in a time series study prior to estimation. The study tested for stationarity within the framework of the Augmented Dickey-Fuller (ADF) test. The ADF test is relevant in order to avoid the likelihood of a spurious regression.

The ADF test for unit root requires the estimation of equation of the form:

$$\Delta y_t = \alpha_0 + \partial y_{t-1} + \sum_{i=1}^{P} \beta_i \Delta y_{t-1} + \varepsilon_t \ldots \ldots . (7)$$

y_t is a vector for the time series variables in a particular regression. With respect to this study it is the variables under consideration.

t represents time trend, Δ represents the first difference operator, μ_t is the error term and P represents the optimal lag length.

The ADF test for unit root tests the null hypothesis of unit root against the alternative that the variable in question is stationary. Thus acceptance of the null hypothesis implies that the series has a unit root and hence nonstationary. Similarly, rejection of the null hypothesis of unit root implies the series is stationary.

3.4.2 Cointegration Analysis

As argued above, nonstationarity in time series data poses serious estimation challenges to applied researchers. Running a least squares regression with nonstationary variables has a high potential of leading us into nonsensical conclusions. A way forward then, is to difference the series until stationarity is achieved and then we perform some inference on the stationary differenced series. However, this approach is not without problems; the model in difference series cannot help us say anything about the long-run impact of the variables under investigation. Luckily, there is one special instance where we can retain the long-run information in the data and still make right inference about the relationships being studied. This occurs when the vector of the time series being studied are cointegrated.

The cointegration procedure was first introduced by Granger (1981). Cointegration refers to a linear combination of nonstationary variables (Enders, 2010). The cointegration procedure enables us to investigate the long-run relationship among the variables under consideration in the model. It therefore enables the study to investigate the long run equilibrium relationship among per capita CO_2 emissions and the factors (variables) affecting it.

There are a number of methods for undertaking a cointegration test. These methods include the Engle-Granger (1987), the autoregressive distributed lag (ARDL) model by Pesaran and Pesaran (1997), the fractional cointegration by Granger and Joyeux (1980), Johansen Test (1988) and the Johansen and Juselius (1990).

The study used the Johansen maximum likelihood method of cointegration by Johansen and Juselius (1990). This cointegration method allows researchers to estimate simultaneous models involving two or more variables. It is based on the maximum likelihood estimation and in so doing avoids the inconsistencies of the OLS estimation. It is also more suitable and efficient for determining the number of cointegrating vectors without depending on a random normalization.

3.4.3 The Johansen Cointegration Procedure

Johansen (1988) proposed a framework for considering the possibility of multiple cointegrating vectors. The Johansen cointegration procedure begins with defining vector autoregression (VAR) of a set of y variables of order *p*. This is given as;

$y_t = \mu + \pi_1 y_{t-1} + \pi_2 y_{t-2} + \cdots + \pi_P y_{t-P} + \varepsilon_t$………. (8)

Where y_t is an $n * 1$ vector of variables that are integrated of order one, $I(1)$ and ε_t is an $n * 1$ vector of innovations. π_1 through π_P are $m * m$ coefficient matrices. Subtracting y_{t-1} from both sides of equation (8) leads to;

$\Delta y_t = \mu + \Gamma_1 \Delta y_{t-1} + \Gamma_2 \Delta y_{t-2} + \Gamma_{P-1} \Delta y_{t-P+1} + \Pi y_{t-P} + \varepsilon_t$…….. (9)

Where $\Gamma_1 = \pi_1 - I, \Gamma_2 = \pi_2 - \Gamma_1$, $\Gamma_3 = \pi_3 - \Gamma_2$ and $\Pi = I - \pi_1 - \pi_2 - \cdots - \pi_P$

Equation (9) can be rewritten as;

$$\Delta y_t = \mu + \Pi y_{t-1} + \sum_{i=1}^{P-1} \Gamma_i \Delta y_{t-i} + \varepsilon_t \ldots \ldots . . (10)$$

Where $\Pi = \sum_{i=1}^{P} \pi_i - I$ and $\Gamma_i = -\sum_{j=i+1}^{P} \pi_j$

If the coefficient matrix $\boldsymbol{\Pi}$ has reduced rank $r < n$, then there exists $n * r$ matrices α and β each with rank r such that $\Pi = \alpha\beta^{'}$ and $\beta^{'} y_t$ is stationary. r is the number of cointegrating relationships, the elements of α are known as the adjustment parameters in the vector error correction model and each column of β is a cointegrating vector.

Johansen put forward two likelihood ratio tests namely; the trace test and the maximum eigenvalue test. The trace test tests the null hypothesis of *r* cointegrating vectors against the alternative hypothesis of *n* cointegrating vectors.

The test statistic is given by;

$$J_{trace} = -Tln \sum_{i=r+1}^{n} (1 - \hat{\lambda}_i)$$

The maximum eigenvalue tests the null hypothesis of r cointegrating vectors against the alternative hypothesis of $(r+1)$ cointegrating vectors. The test statistic for the maximum eigenvalue test is computed by the following formula:

$$J_{max} = -Tln(1-\hat{\lambda}_{r+1})$$

T denotes the sample size and $\hat{\lambda}_i$ is the i^{th} largest canonical correlation. None of the tests above follows the chi square distribution but rather a different distribution tabulated by Johansen and Juselius (1990) and are also provided by most econometric softwares (Hjamarsson and Osterholm, 2007).

In this study, the vector error-correction model (VECM) with a lag order of P is modelled as:

$$\Delta\ln(CO_2)_t = \alpha_0 + \sum_{i=1}^{P} \alpha_{1i}\Delta\ln(CO_2)_{t-i} + \sum_{i=0}^{P} \alpha_{2i}\Delta lnY_{t-i} + \sum_{i=0}^{P} \alpha_{3i}Y_{t-i}^2 + \sum_{i=0}^{P} \alpha_{4i}\Delta lnTO_{t-i} + \sum_{i=0}^{P} \alpha_{5i}\Delta lnEC_{t-i} + \sum_{i=0}^{P} \alpha_{6i}\Delta\ln(URBAN)_{t-i} + \varphi ECM_{t-1} + \varepsilon_{t-i} \quad \ldots\ldots\ldots (11)$$

All variables are as defined already. ECM_{t-1} is the error correction term, the residuals that are obtained from the estimated cointegrating model of equation (11). Δ denotes the first differenced form of the variables in the model.

The coefficients $\alpha_{1i}, \alpha_{2i}, \alpha_{3i}, \alpha_{4i}, \alpha_{5i}, and\ \alpha_{6i}$ measure the (short-run) impact a change in the independent variable has on a change in the dependent variable respectively. φ is the coefficient on the error correction term which represents the speed of the adjustment parameter which measures the speed of adjustment to long run equilibrium after a shock to the system. The lag length used in place of P is automatically selected by the econometric software employed.

3.4.4 Granger Causality Test

Granger Causality refers to the effect of past values of Y_t on the current values of X_t. It measures whether current and past values of Y_t help to forecast future values of X_t (Enders, 2010). In the presence of cointegrating vectors Granger causality test is conducted based on the error correction model. Such that:

$$\Delta Y_t = \theta_0 + \sum_{i=1}^{n} \theta_{1i} \Delta Y_{t-i} + \sum_{j=1}^{m} \theta_{2j} \Delta X_{t-j} + \psi_{1i} \varepsilon_{t-1} + \mu_t \dots \dots .. (12)$$

$$\Delta X_t = \sigma_0 + \sum_{i=1}^{n} \sigma_{1i} \Delta X_{t-i} + \sum_{j=1}^{m} \sigma_{2j} \Delta Y_{t-j} + \psi_{2i} \varepsilon_{t-1} + \nu_t \dots \dots .. (13)$$

Where Y_t represent CO_2 emissions per capita and X_t the explanatory variables respectively. n and m are the optimum lags. μ_t *and* ν_t are error terms.

In the Granger Causality test regression equations above; X does not Granger cause Y, if parameters on the lagged differences on X in equation (12) are jointly zero and Y does not Granger cause X if parameters on the lagged differences on Y in equation (13) are jointly zero. These form the null hypothesis;

1) H_0: $\theta_{21} = \theta_{22} = \theta_{23} = \dots = \theta_{2m} = 0$, X does not Granger cause Y,

This implies that any of the explanatory variables does not Granger cause the per capita CO_2 emissions.

2) H_0: $\sigma_{21} = \sigma_{22} = \sigma_{23} = \dots = \sigma_{2m} = 0$, Y does not Granger Cause X

This implies CO_2 emissions per capita does not Granger cause any of the explanatory variables.

The results of the test are interpreted as: rejection of the first hypothesis implies *X* Granger cause *Y*, rejection of the second hypothesis implies *Y* Granger Cause *X*, concurrent rejection of the two hypotheses indicates bidirectional causality, acceptance of both indicates there is no causal relationship between *X* and *Y*, if the first hypothesis is accepted and the second rejected, there is a unidirectional causality from the *X* variable to the *Y* variable, and if the first hypothesis is rejected and the second accepted, then causality runs unidirectional from *Y* to *X*.

CHAPTER FOUR

ANALYSIS OF DATA AND DISCUSSION OF EMPIRICAL RESULTS

4.1 Introduction

This chapter presents and discusses the results of the study. It includes the result of the unit root, cointegration and the Granger Causality tests. The study employed the use of the Johansen Cointegration method to investigate the effect of trade openness and economic growth on carbon dioxide emissions. The Augmented Dickey Fuller (ADF) test was used to study the stationarity features of the variables under consideration. The econometric software used for the analysis is Eviews 7.

4.2 The Unit Root Test

The time series features of the variables were investigated to determine the order of integration of the choice variables. The existence of unit root in a variable implies nonstationarity and estimations based on nonstationary variables are very likely to lead to the production of spurious results (Granger, 1969). Nonstationarity is very common to most time series variables and in order to shun spurious regressions, the test for stationarity of variables is imperative.

The study applied the Augmented Dickey-Fuller (ADF) introduced by Dickey and Fuller (1979) to perform the unit root test. The ADF test involves testing the null hypothesis of nonstationarity (presence of unit root) against the alternative hypothesis of stationarity (no unit root).

Table 4.1 presents the results of the unit root test. The test includes both constant and constant with trend at the levels and also constant and with trend at the first difference.

At the log level (constant only) all the variables were non-stationary. The variables were then tested again by adding trend. With the addition of the trend only CO_2 was found to be weakly stationary at 10% level of significance. Due to the nonstationarity of the variables at the log levels, the variables were first differenced. At the first difference without trend the variables were found to be stationary. CO_2, *Y*, *W*, *TO* and *EC* are stationary at 1% level of significance and *URBAN* at 5% significant level. At the first difference with trend, all the variables were found to be stationary at the 1% significant level with the exception of *URBAN* which is significant at 10% level of significance. The results therefore show that the variables are log level nonstationary and therefore exhibit unit root. They however achieved stationary after first differencing. All the variables are therefore integrated of order one, $I(1)$.

Table 4.1 Results of Unit Root Test

	Log Level		First Difference	
Variable	Constant	Constant & Trend	Constant	Constant & Trend
CO_2	-2.142667	-3.200257*	-5.955999***	-6.153304***
Y	-0.568629	-1.009812	-4.408017***	-2.862438
W	0.206663	-0.580315	-4.541611***	-6.098525***
TO	-0.977345	-3.187907	-5.270284***	-5.194626***
EC	-2.196614	-2.28894	-6.309102***	-6.272041***
URBAN	-1.323178	-0.996291	-3.975102***	-3.947196**

Note: *, **, ***, represent the rejection of the null hypothesis of unit root at the 10%, 5% and 1% level of significance respectively. The critical values are obtained from the MacKinnon (1996) for the ADF test.

The economic implication of the presence of unit roots in the data is that shock to any of the variables in this study will have permanent effect. Mean reverting mechanism is absent in all the variables. As pointed above, the statistical implication for the presence of unit root is that it could lead to estimation of spurious relationships, unless the underlying series are cointegrated. We thus proceed to present the results of the cointegration test.

4.2 The Johansen Maximum Likelihood Cointegration Test

Now that it has been established that all the variables are integrated of order one, $I(1)$, the study goes ahead to test for cointegration based on Johansen and Juselius (1990). Cointegration allows for the testing of the long-run equilibrium relationships (cointegration) among the series. At the 5% level of significance, both the trace and maximum eigenvalue tests indicate one cointegrating equation (CE) among the variables. Thus, the null hypothesis of no cointegration relationship among the variables is flatly rejected at the 5% level of statistical significance, by both the trace test and the maximum eigenvalue test. The optimal lag length of one was selected based on SC.

Table 4.2 presents the Johansen Cointegration test results for all the variables (carbon dioxide, real GDP per capita, real GDP per capita squared, trade openness, energy consumption and urbanization) in the study;

Table 4. 2 Johansen Cointegration Test

Trace Test					Maximum-eigenvalue Test		
Hypothesized No. of CE(s)	Eigen Value	Trace Statistic	0.05 Critical value	Prob**	Max-Eigen Statistic	0.05 Critical Value	Prob**
None *	0.804612	134.5883	103.8473	0.0001	60.41248	40.95680	0.0001
At most 1	0.505713	74.17580	76.97277	0.0801	26.07163	34.80587	0.3733
At most 2	0.404320	48.10417	54.07904	0.1532	19.16789	28.58808	0.4781
At most 3	0.305598	28.93628	35.19275	0.2019	13.49408	22.29962	0.5092
At most 4	0.277854	15.44220	20.26184	0.2021	12.04452	15.89210	0.1834
At most 5	0.087739	3.397682	9.164546	0.5091	3.397682	9.164546	0.5091

Note: Trace test indicates 1 cointegrating eqn(s) at the 0.05 level, * denotes rejection of the hypothesis at the 0.05 level and **MacKinnon-Haug-Michelis (1999) p-values. Max-eigenvalue test indicates 1 cointegrating eqn(s) at the 0.05 level**,** * denotes rejection of the hypothesis at the 0.05 level and **MacKinnon-Haug-Michelis (1999) p-values.

Since the results from the cointegration test indicate strong evidence of cointegration relationship among the variables, we can estimate the long-run equilibrium relationships among the variables consistently without falling into the trap of spurious relationships. This is taken up next.

4.3 The Long-Run Relationship

Table 4.3 shows the estimates of the normalized long-run relationship among the variables of the study.

Table 4.3 Estimates of the Long-Run Cointegration Model

Dependent Variable: $lnCO_2$			
Regressors	Coefficient	Standard Error	t-Statistics
Constant	0.373085		
lnY	0.008499**	(0.00350)	-2.42829
lnW	-1.85E-05**	(0.000007)	2.64286
lnTO	0.003336***	(0.00047)	-7.09787
lnEC	-0.002811***	(0.00056)	5.01964
lnURBAN	-0.041842***	(0.01273)	3.28688

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

The results of the long-run model above show that all the coefficients of the variables are less than one (1), indicating they are inelastic. However, all the independent variables are found to be significant at 1% and 5%. In Table 4.3 are the estimated long-run elasticities when the equation is normalized on CO_2 emissions per capita.

The results from the estimated long-run equilibrium relationship presented in Table 4.3 indicate a positive relationship between per capita carbon dioxide emissions and real GDP per capita. It is statistically significant at 5%. It shows that a 1% increase in real GDP per capita will lead to a 0.0085% increase in the emissions of per capita CO_2 emissions. This means that in the long-run an increase in economic growth in Ghana will lead to a small rise (percentage terms) in the emissions of CO_2. The results also show a negative relationship between *lnW* (real GDP per capita squared) and CO_2 emissions. It is statistically significant at 5%. The signs of real GDP per capita (*lnY*) and real GDP per capita squared (*lnW*) meet the expectation of the study. The study expected real GDP per capita and real GDP per capita squared to have positive and negative signs respectively. This outcome is in line with the assertion of the Environmental Kuznets Curve (EKC) hypothesis. The EKC postulates that, as an economy grows (GDP per capita increases), the emissions of pollution (CO_2) increases, attains a peak and then begins to fall. It depicts an inverted U-shaped nature between CO_2 emissions and economic growth. The result (sign) of the real GDP per capita (*lnY*) is consistent with the findings of Ahmed and Long (2012), Iwata et al., (2010), Song et al., (2008), Narayan and Nayaran (2010), Kaufmann et al. (1998), and Schmalensee et al. (1998). However it is contrary to the results of Wang (2012), Orubu and Omotor (2011) for organic water pollutant, Akpan and Chuku (2011) and Fodha and Zaghdoud (2010) using SO_2 emissions.

A negative sign of real GDP per capita squared (*lnW*) portrays the inverted U-Shaped nature of the EKC (Jayanthakumaran et al., 2012, Friedl and Getzner, 2003, Iwata et al., 2010). Considering the signs of *lnY* and *lnW*, it can be said that there exists an inverted U-shaped nature (relationship) between carbon dioxide emissions and economic growth in Ghana. As the economy grows (GDP per capita increases), carbon dioxide emissions increases. However, with higher economic growth, carbon dioxide emissions fall.

The study finds a positive relationship between per capita carbon dioxide emissions and trade openness (*TO*). It is statistically significant at 1%. It shows that a 1% increase in trade openness will lead to a 0.0033% rise in the emissions of per capita CO_2 emissions. This means that in the long-run an increase in trade openness in Ghana will lead to a small rise (percentage terms) in the emissions of CO_2. This result was partly expected since the study expected trade openness to be either positive or negative. This suggests that Ghana's trade (imports and exports) has contributed to the increase in the emissions of CO_2. An increase in trade openness causes an increase in CO_2 emissions but however by a small margin.

This finding is consistent with the assertion of the Pollution Haven Hypothesis (PHH). The PHH states that regulations of the environment will move polluting activities of tradable commodities to poorer countries (Eskeland and Harrison, 2003). It predicts that with globalization and trade liberalization, multinational firms in advanced countries where environmental regulations are strict will shift the production of their pollution intensive commodities to regions (developing countries) where environmental regulations are laxer. When this happens the developing countries are more polluted. The hypothesis therefore expects trade openness to have a positive impact on the emissions of CO_2. Meaning the contribution of foreign trade to CO_2 emissions is positive considering the time under consideration.

Energy consumption (*EC*) does not meet the expectation of the study by having a negative relationship with the emissions of CO_2. This implies that an increase in *E*C will lead to a decrease in the emissions of CO_2. It is statistically significant at 1%. It shows that a 1% increase in energy consumption will lead to a 0.003% decrease in per capita CO_2 emissions. This means that in the long-run an increase in energy consumption in Ghana will lead to a small decrease (percentage terms) in the emissions of CO_2. This result is inconsistent with the findings of Halicioglu (2009), Jayanthakumaran et al., (2012), Al-mulali (2012), Alam et al., (2012) and Sharma (2011).

Last but not least, urbanization (*URBAN*) also does not meet the expectation of the study by having a positive sign with the emissions of CO_2. An increase in urbanization will lead to a decrease in the emissions of CO_2 in the country. The variable *URBAN* is statistically significant at 1%. In the long-run urbanization will cause a decrease in CO_2 emissions in Ghana. As the growth rate at which people move to settle in the urban areas increase, the emissions of CO_2 decrease. Specifically, a 1% increase in *URBAN* will cause a 0.0418% decrease in CO_2 emissions. This result is consistent with that of Sanglimsuwan (2011) and Sharma (2011) in a similar study.

4.4. Results of the Short-Run/Vector Error Correction Model (VECM)

By invoking the Granger representation theorem (Granger, 1983, Engle and Granger, 1987) that "if the vector time series variables in Z are cointegrated, then they can be represented as an ECM; and vice versa, if the Z has an ECM representation, then the variables in vector Z are cointegrated", we estimate the error correction representation of the above cointegration relationship. The error correction model captures the short-run dynamics of the model. The coefficient estimates are thus the short run elasticities, given our log-log specification.

Table 4.4 presents the coefficients, standard errors, t-statistics and the probability values of the VECM model.

Table 4. 4 Estimates of the Short-Run /VECM Model

Dependent Variable: D(lnCO2)

Regressors	Coefficients	Standard Error	t-Statistics	Prob.
D(lnCO_2(-1))	-0.327992**	0.141478	-2.31832	0.0277
D(lnY(-1))	-0.014835***	000.005166	-2.871641	0.0076
D(lnW(-1))	2.91E-05***	9.89E-06	2.942331	0.0063
D(lnTO(-1))	-0.000976*	0.000526	-1.855038	0.0738

D(lnEC(-1))	0.001776***	0.000385	4.607138	0.0001
D(lnURBAN(-1))	0.011173	0.016892	0.661425	0.5136
C	-0.002845	0.004552	-0.624993	0.5369
ECT	-0.349012***	0.084499	-4.130351	0.0003

R-squared	0.566469	Mean dependent var	0.001299
Adjusted R-squared	0.461823	S.D. dependent var	0.035448
S.E. of regression	0.026005	Akaike info criterion	-4.272255
Sum squared resid	0.019611	Schwarz criterion	-3.923949
Log likelihood	87.03673	Hannan-Quinn criter.	-4.149461
F-statistic	5.413216	Durbin-Watson stat	2.047612
Prob(F-statistic)	0.000477		

Note: *, **, ***, represent 10%, 5% and 1% significant levels respectively. ECT represents the error correction term.

The results of the short-run model give an R-squared (R^2) of 0.566469. It implies that all the independent variables (namely; *lnY*, *lnW*, *lnTO*, *lnEC* and *lnURBAN*) together account for or explain nearly 56.65 % of the variations in the dependent variable ($lnCO_2$). This is good and speaks well of the model because the independent variables account for or explain a greater variations in the dependent variable. The F-statistic of 5.413216 is good and renders the model fit. The model also passed the residual diagnostics tests of normality (using the Jarque-Bera statistic), serial correlation (Breusch-Godfrey Serial Correlation LM Test) and the hetereoskedasticity test (Breusch-Pagan-Godfrey and the ARCH). They all show p-values greater than 5%. These imply that all the variables are jointly normally distributed; there is no autocorrelation and hetereoskedasticity (see appendix 3.2 for detailed results). These give an indication that the model is good and can therefore be used for analysis.

The results show that the error correction term (ECT) has a negative coefficient and its probability value is less than 5%. The negative coefficient implies the dynamic consistency and stability of the model. The ECT is statistically significant at 1% level of significance. The statistical significance of the coefficient gives a signal of joint significance of the coefficients of the long-run model under the VECM structure. It also buttresses the existence of a long-run equilibrium relationship (according to the Granger representation theorem) among the variables as shown under the Johansen Cointegration test. It has a coefficient of 0.349012 and this suggests that the system corrects its previous period's disequilibrium by 34.9% a year.

The coefficients of the VECM are short-run elasticities. The results show that out of the 8 coefficients, 6 of them are statistically significant. The first lag of carbon dioxide emissions per capita ($lnCO_2$(-1)) shows a negative sign. This suggests that a 1% increase in carbon dioxide emissions per capita lagged 1 year will cause CO_2 emissions to fall by 0.328% in the short-run.

Therefore, there exists a negative relationship between carbon dioxide emissions per capita and its lag (1 year). It is statistically significant at 5%. There exists a negative relationship between the lag of real GDP per capita (lnY(-1)) and carbon dioxide emissions per capita ($lnCO_2$). A 1% increase in real per capita GDP lagged 1 year will lead to a 0.0148% decrease in the emissions of CO_2 in the short run. This is statistically significant at 1%. This outcome is inconsistent with the estimates of the long-run model since both show different signs. However both are statistically significant.

The first lag of real GDP per capita squared (lnW (-1)) shows a positive sign. Implying a positive relationship between real GDP per capita squared (W) and CO_2 emissions in the short-run. The first lag of W indicates that a 1% increase in W lagged 1 year will lead to a 0.00003% rise in the emissions of CO_2 in the short-run. It is statistically significant at 1%. This outcome is also inconsistent with the estimates of the long-run model. Both are statistically significant though at different levels of significance. The long-run coefficient is statistically significant at 5% level of significance.

The first lag of trade openness (*lnTO*(-1)) shows a negative impact on CO_2 emissions. This is dissimilar to the sign of *lnTO* in the long-run. There is therefore no conformity between the long-run and short-run estimates with relation to *TO*. Specifically, a 1% increase in the *TO* lagged 1 year will cause CO_2 to fall by 0.001% in the short-run. It is statistically significant at 10%. The long-run estimates also show *TO* is statistically significant but at 1% level of significance.

With the energy consumption (*EC*) variable, the short-run estimates show that *EC* lagged 1 year is statistically significant at 1%. Its coefficient has a positive sign and this is inconsistent with the estimates of the long-run model. Specifically, a 1% increase in *EC* lagged 1 year (*lnEC*(-1)) will cause CO_2 emissions to increase by 0.002% in the short-run.

Lastly, the results show that the coefficient of *URBAN* lagged 1 (*lnURBAN*(-1)) is statistically insignificant. However in the long-run it is statistically significant at 1%. Its positive sign in the short-run does not conform to the sign in the long-run model. Specifically, a 1% increase in the values of *URBAN* lagged 1 year will lead to a 0.011% increase in carbon dioxide emissions.

4.5 Granger Causality Test

For this sub-section, the study conducts Granger-Causality test to investigate the bivariate causal relationship between CO_2 emissions per capita and each of the independent variables. Finding causality among variables does not literally mean finding whether one variable necessarily causes one variable. Granger-Causality is more of prediction than the mere meaning of causation. It proposes that while the past can cause or predict the future, the future cannot cause or predict the past. *X* Granger Causes *Y* if the past values of *X* can be used to predict *Y* more precisely than merely using the past values of *Y*.

The first log difference of the variables are used in this analysis because Granger Causality test works on the assumption of stationary variables and the first log differences are stationary. In running the test, real GDP per capita squared (*W*) was dropped since it is not a key variable. Table 4.5 shows the result of the Granger-Causality test.

Table 4.5: Results of Granger Causality Test

Null Hypothesis:	**F-Statistic**	**Prob**
D*lnY* does not Granger Cause D*ln*CO_2	0.0619	0.8050
D*ln*CO_2 does not Granger Cause DlnY	0.00307	0.9562
D*lnTO* does not Granger Cause D*ln*CO_2	0.22602	0.6375
DlnCO_2 does not Granger Cause D*lnTO*	0.53843	0.4681
D*lnURBAN* does not Granger Cause D*ln*CO_2	0.00287	0.9576
D*ln*CO_2 does not Granger Cause D*lnURBAN*	1.26947	0.2678
D*lnEC* does not Granger Cause D*ln*CO_2	11.0536	0.0021
D*ln*CO_2 does not Granger Cause D*lnEC*	0.61656	0.4378

From Table 4.5, the null hypothesis that real income (*DlnY*) does not Granger Cause CO_2 emissions (*Dln*CO_2) is not rejected since the probability value is as high as 0.8050. Also the null hypothesis that *Dln*CO_2 (carbon dioxide emissions) does not Granger Cause *DlnY* is not rejected since its probability value is as high as 0.9562. The implication here is that neither the past values of real income nor CO_2 emissions cause or predict the current values of CO_2 emissions and real income respectively.

Also, the null hypothesis that trade openness *(DlnTO)* does not Granger Cause CO_2 emissions (*DlnCO$_2$*) is not rejected since the probability value is as high as 0.6375. The null hypothesis; *DlnCO$_2$* (carbon dioxide emissions) does not Granger Cause *DlnTO* is not rejected since its probability value is as high as 0.4681.

It is also evident from Table 4.5 that the null hypothesis that urbanization (*DlnURBAN*) does not Granger Cause CO_2 emissions (*DlnCO$_2$*) is not rejected since the probability value is as high as 0.9576. Also the null hypothesis that *DlnCO$_2$* (carbon dioxide emissions) does not Granger Cause *DlnURBAN* is not rejected since its probability value is as high as 0.2678. The implication here is that neither the past values of urbanization nor CO_2 emissions cause or predict the current values of CO_2 emissions and urbanization respectively.

The null hypothesis that *DlnEC* (energy consumption) does not Granger Cause *DlnCO$_2$* (CO_2 emissions) is flatly rejected at 1% level of significance given the probability value 0.0021. However the null hypothesis that *DlnCO$_2$* does not Granger Cause *DlnEC* is not rejected since the probability value is as high as 0.4378. The implication here is that there is unidirectional causality running from energy consumption (*DlnEC*) to CO_2 emissions (*DlnCO$_2$*) with no feedback effect.

CHAPTER FIVE

FINDINGS, CONCLUSION AND RECOMMENDATION

5.1 Introduction

This chapter presents the major findings, conclusion, recommendations, suggestions for further studies and limitations of the study.

5.2 Major Findings of the Study

The study conducted a unit root test using the ADF test and found all the variables to be $I(1)$. The Johansen Cointegration Test found a long-run relationship among the series.

A theoretically expected statistically significant positive relationship was found to exist between real GDP per capita (Y) and CO_2 emissions per capita in the long-run but negative in the short-run. Again, a theoretically expected statistically significant negative relationship was found to exist between real GDP per capita squared and CO_2 emissions per capita in the long-run but positive in the short-run. The study also found a statistically significant positive relationship existing between trade openness (TO) and per capita CO_2 emissions in the long-run but negative in the short-run, energy consumption (EC) and urbanization ($URBAN$) were found to have negative impacts on CO_2 emissions per capita in the long-run. $URBAN$ was however statistically insignificant in the short-run.

The Granger Causality test found a unidirectional causality running from energy consumption to CO_2 emissions per capita with no reverse causality observed.

5.3 Conclusion

This study fills the gap in the literature on economic growth and carbon dioxide emissions in Ghana. It sought to examine the effect of trade openness and economic growth on CO_2 emissions in Ghana using annual time series data from the World Bank's World Development Indicators between the period 1971 and 2009. It also investigated the impact of other variables like energy consumption and urbanization on the emissions of carbon dioxide for the same period mentioned afore. Econometrically, the study employed the use of Johansen and Juselius (1990) Cointegration Test and the Vector Error Correction Model to investigate the feasible long-run and short-run relationship and effects among the variables under consideration. Granger Causality test was also carried out to find the causality among the variables.

The study found all the variables to be integrated of order one, $I(1)$ by applying the use of the Augmented Dickey-Fuller test. The Johansen Cointegration test established that there is 1 cointegrating equation among the variables. Upon achieving cointegration, the study went on to run the VECM. The study found a positive relationship between real GDP per capita and carbon dioxide emissions. Implying that, growth is pollution intensive in Ghana. It also found real GDP per capita squared to have a negative impact on the emissions of carbon dioxide. The positive and negative signs of real GDP per capita (used as a proxy for economic growth) and real GDP per capita squared respectively indicate that the assertion of the Environmental Kuznets Curve holds for Ghana. Therefore there exists an inverted U-shaped nature between economic growth and carbon dioxide emissions in Ghana for the time period considered.

The study also found a positive relationship between trade openness and carbon dioxide emissions. This indicates that trade is pollution intensive in Ghana. Energy consumption and urbanization were found to have negative impacts on carbon dioxide emissions.

The Granger Causality test revealed a unidirectional causality running from energy consumption to CO_2 emissions per capita with no feedback effect.

5.4 Policy Recommendations

A study about greenhouse gases (GHGs) is very important lately as a result of their contribution to climate change and its consequences on human life, biodiversity, the environment and vegetation. Moreover, the study of carbon dioxide and factors that contribute to its emissions is much more important since it's the largest GHG emitted hence the largest contributor to climate change.

The study recommends that the nation engages in less polluting activities in its economic growth and trade expeditions since they are found to have positive impacts on CO_2 emissions in the long-run. The nation should be mindful of the kind of multinational corporations allowed to produce in it. It should allow corporations whose activities produce relatively less CO_2 or virtually do not produce CO_2. The study recommends that the nation imports items that are less carbon dioxide emitting into the country.

Regardless of this outcome, the EPA has projected there is a high potential for CO_2 emissions to increase in the country. The study recommends that despite the negative relationship between energy consumption, urbanization and carbon dioxide emissions, the government should embark on less polluting (carbon dioxide emitting) activities in its developmental, trade expeditions and energy generation so as to reduce CO_2 the more. In the quest of economic growth and development, the country should opt for less polluting (carbon dioxide emitting) projects so as to curb the harsh effects of the consequences of climate change majorly caused by CO_2 emissions.

5.5 Practical Limitations and Suggestions for Future Research

The carbon dioxide emissions topic and factors that account for its emissions are very less discussed and researched into in Ghana. Considering carbon dioxide emissions and its contribution to climate change and global warming, this topic is very relevant to be researched into the more. With the limitation of data availability for all variables, the study could not cover a very long span. It is therefore suggested that with the availability of data, other researchers should further research into this topic on a very long term span. It is also suggested that future studies should consider different measurement of variables (for variables such as carbon dioxide and energy consumption) and their results compared with this study for a very concrete conclusion to be drawn. Lastly, the effects of other variables like population growth, FDI and gross fixed capital formation on carbon dioxide emissions can also be investigated.

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APPENDICES

APPENDIX 1: RESULTS OF ADF TEST

Null Hypothesis: $lnCO_2$ has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.142667	0.2299
Test critical values:	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: $lnCO_2$ has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.200257	0.0996
Test critical values:	1% level	-4.219126	
	5% level	-3.533083	
	10% level	-3.198312	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: $D(lnCO_2)$ has a unit root
Exogenous: Constant
Lag Length: 2 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.955999	0.0000
Test critical values:	1% level	-3.632900	
	5% level	-2.948404	
	10% level	-2.612874	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D($lnCO_2$) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 2 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.153304	0.0001
Test critical values:	1% level	-4.243644	
	5% level	-3.544284	
	10% level	-3.204699	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnY has a unit root
Exogenous: Constant
Lag Length: 6 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.568629	0.8640
Test critical values:	1% level	-3.653730	
	5% level	-2.957110	
	10% level	-2.617434	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnY has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.009812	0.9303
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnY) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.408017	0.0012
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnY) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 8 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.862438	0.1884
Test critical values:	1% level	-4.309824	
	5% level	-3.574244	
	10% level	-3.221728	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnW has a unit root
Exogenous: Constant
Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		0.206663	0.9694
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnW has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 1 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.580315	0.9744
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnW) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-4.541611	0.0008
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnW) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.098525	0.0001
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnTO has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-0.977345	0.7516
Test critical values:	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnTO has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 4 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.187907	0.1037
Test critical values:	1% level	-4.252879	
	5% level	-3.548490	
	10% level	-3.207094	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnTO) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.270284	0.0001
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnTO) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-5.194626	0.0008
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnEC has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.196614	0.2108
Test critical values:	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnEC has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-2.288940	0.4295
Test critical values:	1% level	-4.219126	
	5% level	-3.533083	
	10% level	-3.198312	

Null Hypothesis: D(lnEC) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.309102	0.0000
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnEC) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-6.272041	0.0000
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnURBAN has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-1.323178	0.6088
Test critical values:	1% level	-3.615588	
	5% level	-2.941145	
	10% level	-2.609066	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: lnURBAN has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*

Augmented Dickey-Fuller test statistic		-0.996291	0.9326
Test critical values:	1% level	-4.219126	
	5% level	-3.533083	
	10% level	-3.198312	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnURBAN) has a unit root
Exogenous: Constant
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.975102	0.0040
Test critical values:	1% level	-3.621023	
	5% level	-2.943427	
	10% level	-2.610263	

*MacKinnon (1996) one-sided p-values.

Null Hypothesis: D(lnURBAN) has a unit root
Exogenous: Constant, Linear Trend
Lag Length: 0 (Automatic - based on SIC, maxlag=9)

		t-Statistic	Prob.*
Augmented Dickey-Fuller test statistic		-3.947196	0.0197
Test critical values:	1% level	-4.226815	
	5% level	-3.536601	
	10% level	-3.200320	

*MacKinnon (1996) one-sided p-values.

APPENDIX 2: Results of the Johansen Cointegration Test

Date: 03/20/13 Time: 22:17
Sample (adjusted): 1973 2009
Included observations: 37 after adjustments
Trend assumption: No deterministic trend (restricted constant)
Series: *lnCO$_2$ lnY lnW lnTO lnEC lnURBAN*
Lags interval (in first differences): 1 to 1

Unrestricted Cointegration Rank Test (Trace)

Hypothesized No. of CE(s)	Eigenvalue	Trace Statistic	0.05 Critical Value	Prob.**
None *	0.804612	134.5883	103.8473	0.0001
At most 1	0.505713	74.17580	76.97277	0.0801
At most 2	0.404320	48.10417	54.07904	0.1532
At most 3	0.305598	28.93628	35.19275	0.2019
At most 4	0.277854	15.44220	20.26184	0.2021
At most 5	0.087739	3.397682	9.164546	0.5091

Trace test indicates 1 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 *	0.804612	60.41248	40.95680	0.0001
At most 1	0.505713	26.07163	34.80587	0.3733
At most 2	0.404320	19.16789	28.58808	0.4781
At most 3	0.305598	13.49408	22.29962	0.5092
At most 4	0.277854	12.04452	15.89210	0.1834
At most 5	0.087739	3.397682	9.164546	0.5091

Max-eigenvalue test indicates 1 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 Cointegrating Coefficients (normalized by b'*S11*b=I):

lnCO$_2$	lnY	lnW	lnTO	lnEC	lnURBAN	C
-19.94698	0.169533	-0.000369	0.066536	-0.056073	-0.834616	7.441928
2.359087	0.427416	-0.000812	-0.059906	0.034244	2.208921	-74.33236
-30.75691	-0.569231	0.001084	-0.028232	0.124071	-0.758405	40.55145

-5.631722	0.410807	-0.000734	-0.034877	-0.009600	0.285524	-50.05373
-33.43441	-0.159177	0.000352	0.024993	0.059889	0.265081	2.693851
-12.75395	-0.107078	0.000268	-0.015040	0.009971	1.089799	5.610574

Unrestricted Adjustment Coefficients (alpha):

D($\ln CO_2$)	0.017214	0.007489	-0.008031	0.001183	0.005420	-0.002870
D(lnY)	-0.811095	-1.220558	-2.110133	-4.670354	0.556265	-1.316532
D(lnW)	-735.1900	-596.4313	-1121.155	-2418.502	447.3438	-786.4867
D(lnTO)	-3.657892	3.237276	0.369549	-1.222363	-3.779215	0.057361
D(lnEC)	3.208810	-4.105113	-5.340941	2.268599	-1.218645	-0.551495
D(lnURBAN)	0.033410	-0.034726	0.099463	0.021763	-0.033272	-0.044753

1 Cointegrating Equation(s): Log likelihood -586.2270

Normalized cointegrating coefficients (standard error in parentheses)

$\ln CO_2$	lnY	lnW	lnTO	lnEC	lnURBAN	C
1.000000	-0.008499	1.85E-05	-0.003336	0.002811	0.041842	-0.373085
	(0.00350)	(6.6E-06)	(0.00047)	(0.00056)	(0.01273)	(0.42773)

Adjustment coefficients (standard error in parentheses)

D($\ln CO_2$)	-0.343359
	(0.08514)
D(lnY)	16.17890
	(37.5587)
D(lnW)	14664.82
	(20228.8)
D(lnTO)	72.96390
	(32.7033)
D(lnEC)	-64.00608
	(41.8456)
D(lnURBAN)	-0.666422
	(0.85783)

2 Cointegrating Equation(s): Log likelihood -573.1912

Normalized cointegrating coefficients (standard error in parentheses)

$\ln CO_2$	lnY	lnW	lnTO	lnEC	lnURBAN	C
1.000000	0.000000	2.26E-06	-0.004324	0.003336	0.081923	-1.768234
		(5.6E-07)	(0.00058)	(0.00060)	(0.01385)	(0.24735)
0.000000	1.000000	-0.001912	-0.116291	0.061708	4.715910	-164.1512
		(4.1E-05)	(0.04229)	(0.04377)	(1.01641)	(18.1529)

Adjustment coefficients (standard error in parentheses)

D($lnCO_2$)	-0.325693	0.006119
	(0.08122)	(0.00186)
D(lnY)	13.29950	-0.659194
	(37.5546)	(0.85970)
D(lnW)	13257.79	-379.5633
	(20252.1)	(463.612)
D(lnTO)	80.60092	0.763533
	(30.7169)	(0.70317)
D(lnEC)	-73.69040	-1.210595
	(39.3563)	(0.90095)
D(lnURBAN)	-0.748343	-0.009178
	(0.85437)	(0.01956)

	Log	
3 Cointegrating Equation(s):	likelihood	-563.6072

Normalized cointegrating coefficients (standard error in parentheses)

$lnCO_2$	lnY	lnW	lnTO	lnEC	lnURBAN	C
1.000000	0.000000	0.000000	0.003598	-0.005783	-0.072931	1.968329
			(0.00098)	(0.00116)	(0.02219)	(0.44208)
0.000000	1.000000	0.000000	-6.815797	7.773565	135.6803	-3324.274
			(1.10391)	(1.30445)	(24.8714)	(495.575)
0.000000	0.000000	1.000000	-3503.427	4032.824	68486.28	-1652549.
			(562.761)	(664.992)	(12679.1)	(252638.)

Adjustment coefficients (standard error in parentheses)

D($lnCO_2$)	-0.078695	0.010690	-2.11E-05
	(0.13842)	(0.00276)	(5.3E-06)
D(lnY)	78.20070	0.541960	-0.000997
	(67.2086)	(1.33878)	(0.00257)
D(lnW)	47741.07	258.6336	-0.459410
	(36267.0)	(722.430)	(1.38590)
D(lnTO)	69.23471	0.553174	-0.000877
	(56.1224)	(1.11794)	(0.00214)
D(lnEC)	90.58046	1.829636	-0.003641
	(62.4310)	(1.24361)	(0.00239)
D(lnURBAN)	-3.807521	-0.065796	0.000124
	(1.41298)	(0.02815)	(5.4E-05)

	Log	
4 Cointegrating Equation(s):	likelihood	-556.8602

Normalized cointegrating coefficients (standard error in parentheses)

$lnCO_2$	lnY	lnW	lnTO	lnEC	lnURBAN	C

1.000000	0.000000	0.000000	0.000000	-0.001149	0.021160	0.055880
				(0.00029)	(0.01031)	(0.12282)
0.000000	1.000000	0.000000	0.000000	-1.006491	-42.58149	298.9947
				(0.46854)	(16.4590)	(196.130)
0.000000	0.000000	1.000000	0.000000	-480.2625	-23143.09	209868.5
				(243.657)	(8559.24)	(101994.)
0.000000	0.000000	0.000000	1.000000	-1.288192	-26.15421	531.5987
				(0.12988)	(4.56233)	(54.3658)

Adjustment coefficients (standard error in parentheses)

D(lnCO_2)	-0.085355	0.011176	-2.20E-05	0.000882
	(0.13981)	(0.00316)	(6.0E-06)	(0.00038)
D(lnY)	104.5028	-1.376655	0.002431	0.241612
	(60.1578)	(1.35839)	(0.00256)	(0.16211)
D(lnW)	61361.40	-734.9045	1.315590	102.8150
	(32816.6)	(741.011)	(1.39875)	(88.4311)
D(lnTO)	76.11872	0.051018	1.98E-05	-0.405114
	(56.1691)	(1.26832)	(0.00239)	(0.15136)
D(lnEC)	77.80434	2.761593	-0.005306	0.531085
	(61.2560)	(1.38319)	(0.00261)	(0.16507)
D(lnURBAN)	-3.930084	-0.056855	0.000108	0.000736
	(1.42184)	(0.03211)	(6.1E-05)	(0.00383)

5 Cointegrating Equation(s):	Log likelihood	-550.8379

Normalized cointegrating coefficients (standard error in parentheses)

lnCO_2	lnY	lnW	lnTO	lnEC	lnURBAN	C
1.000000	0.000000	0.000000	0.000000	0.000000	0.076180	-0.587501
					(0.02367)	(0.09583)
0.000000	1.000000	0.000000	0.000000	0.000000	5.626615	-264.7296
					(10.1713)	(41.1862)
0.000000	0.000000	1.000000	0.000000	0.000000	-139.8514	-59121.26
					(5244.48)	(21236.3)
0.000000	0.000000	0.000000	1.000000	0.000000	35.54661	-189.9036
					(15.5940)	(63.1444)
0.000000	0.000000	0.000000	0.000000	1.000000	47.89722	-560.0890
					(13.6606)	(55.3154)

Adjustment coefficients (standard error in parentheses)

D(lnCO_2)	-0.266579	0.010313	-2.01E-05	0.001018	-0.001392
	(0.18144)	(0.00310)	(5.9E-06)	(0.00037)	(0.00056)
D(lnY)	85.90443	-1.465199	0.002627	0.255514	-0.179975
	(80.7605)	(1.37988)	(0.00262)	(0.16675)	(0.24707)
D(lnW)	46404.73	-806.1115	1.472960	113.9954	-68.29498
	(43953.2)	(750.990)	(1.42669)	(90.7526)	(134.467)

D(lnTO)	202.4745	0.652583	-0.001310	-0.499567	0.147213
	(67.2217)	(1.14856)	(0.00218)	(0.13880)	(0.20565)
D(lnEC)	118.5490	2.955573	-0.005734	0.500628	-1.077918
	(81.6431)	(1.39496)	(0.00265)	(0.16857)	(0.24977)
D(lnURBAN)	-2.817644	-0.051559	9.60E-05	-9.54E-05	0.007076
	(1.88830)	(0.03226)	(6.1E-05)	(0.00390)	(0.00578)

APPENDIX 3: Results of the VECM

Vector Error Correction Estimates
Date: 03/20/13 Time: 23:24
Sample (adjusted): 1973 2009
Included observations: 37 after adjustments
Standard errors in ( ) & t-statistics in [ ]

Cointegrating Eq:	CointEq1
$lnCO_2(-1)$	1.000000
lnY(-1)	-0.008985
	(0.00364)
	[-2.46993]
lnW(-1)	1.95E-05
	(6.9E-06)
	[2.83221]
lnTO(-1)	-0.003430
	(0.00049)
	[-6.96992]
lnEC(-1)	0.002952
	(0.00058)
	[5.10098]
lnURBAN(-1)	0.042717
	(0.01323)
	[3.22812]
C	-0.384847

Error Correction:	$D(lnCO_2)$	D(lnY)	D(lnW)	D(lnTO)	D(lnEC)	D(lnURBAN)
CointEq1	-0.349012	10.20736	11237.11	71.01552	-71.69437	-0.635784

	(0.08450)	(37.3779)	(20116.6)	(32.9493)	(41.0966)	(0.86498)
	[-4.13035]	[0.27309]	[0.55860]	[2.15530]	[-1.74453]	[-0.73503]
D(lnCO$_2$(-1))	-0.327992	12.31038	-1690.464	32.42230	48.38127	1.091512
	(0.14148)	(62.5823)	(33681.4)	(55.1675)	(68.8085)	(1.44824)
	[-2.31832]	[0.19671]	[-0.05019]	[0.58771]	[0.70313]	[0.75368]
D(lnY(-1))	-0.014835	1.861797	929.0405	3.905679	4.385729	-0.032583
	(0.00517)	(2.28513)	(1229.84)	(2.01438)	(2.51247)	(0.05288)
	[-2.87164]	[0.81475]	[0.75542]	[1.93890]	[1.74559]	[-0.61616]
D(lnW(-1))	2.91E-05	-0.002982	-1.501794	-0.007427	-0.007539	6.46E-05
	(9.9E-06)	(0.00437)	(2.35337)	(0.00385)	(0.00481)	(0.00010)
	[2.94233]	[-0.68193]	[-0.63815]	[-1.92667]	[-1.56807]	[0.63837]
D(lnTO(-1))	-0.000976	-0.033652	-25.77798	0.311931	0.005347	-0.003366
	(0.00053)	(0.23285)	(125.319)	(0.20526)	(0.25602)	(0.00539)
	[-1.85504]	[-0.14452]	[-0.20570]	[1.51968]	[0.02089]	[-0.62474]
D(lnEC(-1))	0.001776	-0.208479	-99.02848	-0.164211	-0.308072	0.003255
	(0.00039)	(0.17050)	(91.7647)	(0.15030)	(0.18747)	(0.00395)
	[4.60714]	[-1.22272]	[-1.07916]	[-1.09254]	[-1.64333]	[0.82493]
D(lnURBAN(-1))	0.011173	-8.911683	-3890.850	3.519056	4.554992	0.416680
	(0.01689)	(7.47229)	(4021.54)	(6.58696)	(8.21569)	(0.17292)
	[0.66142]	[-1.19263]	[-0.96750]	[0.53425]	[0.55443]	[2.40968]
C	-0.002845	1.930636	1183.019	1.543299	1.227883	-0.012364
	(0.00455)	(2.01370)	(1083.76)	(1.77511)	(2.21403)	(0.04660)
	[-0.62499]	[0.95875]	[1.09159]	[0.86941]	[0.55459]	[-0.26532]
R-squared	0.566469	0.193700	0.158857	0.181024	0.485666	0.213857
Adj. R-squared	0.461823	-0.000924	-0.044178	-0.016660	0.361516	0.024098
Sum sq. resids	0.019611	3837.343	1.11E+09	2981.900	4638.860	2.054993
S.E. equation	0.026005	11.50314	6190.921	10.14022	12.64756	0.266199
F-statistic	5.413216	0.995251	0.782413	0.915726	3.911942	1.126994
Log likelihood	87.03673	-138.3707	-371.0348	-133.7046	-141.8799	0.976220
Akaike AIC	-4.272255	7.911927	20.48837	7.659707	8.101616	0.379664
Schwarz SC	-3.923949	8.260234	20.83667	8.008014	8.449922	0.727970
Mean dependent	0.001299	1.510977	947.6826	0.964219	0.627707	0.005517
S.D. dependent	0.035448	11.49783	6058.541	10.05680	15.82821	0.269465

Determinant resid covariance (dof adj.)	9110244.
Determinant resid covariance	2112067.
Log likelihood	-584.4231
Akaike information criterion	34.50936

Schwarz criterion	36.86043

APPENDIX 3.1: Coefficients, Standard Errors, t-Statistics and Prob. Values of the VECM

Dependent Variable: D(lnCO_2)
Method: Least Squares
Date: 03/20/13 Time: 23:25
Sample (adjusted): 1973 2009
Included observations: 37 after adjustments

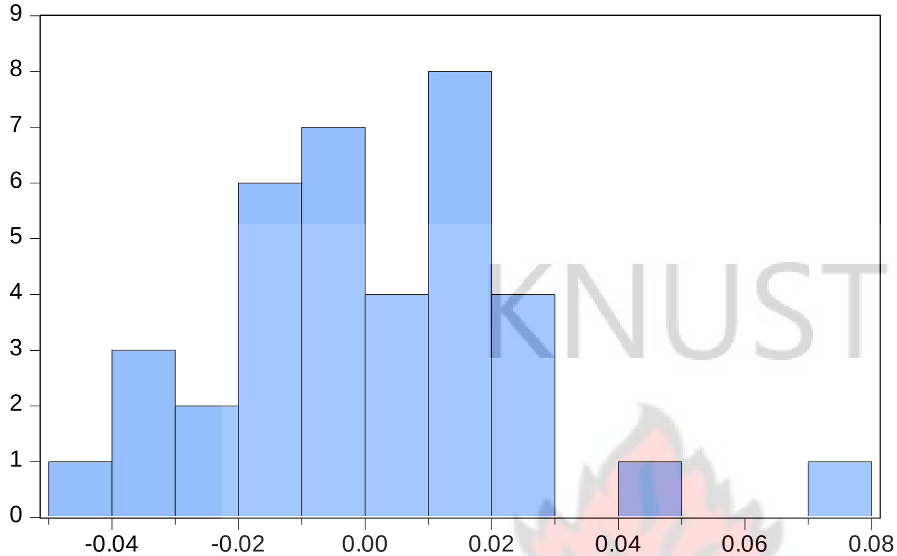
D(lnCO_2) = C(1)*(lnCO_2(-1) - 0.00898463037631*lnY(-1) + 1.9502003737E-05*lnW(-1) - 0.00342974708456*lnTO(-1) + 0.00295157761518*lnEC(-1) + 0.0427170094845*lnURBAN (-1) - 0.384847195858) + C(2)*D(lnCO2(-1)) + C(3)*D(lnY(-1)) + C(4) *D(lnW(-1)) + C(5)*D(lnTO(-1)) + C(6)*D(lnEC(-1)) + C(7) *D(lnURBAN(-1)) + C(8)

	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	-0.349012	0.084499	-4.130351	0.0003
C(2)	-0.327992	0.141478	-2.318320	0.0277
C(3)	-0.014835	0.005166	-2.871641	0.0076
C(4)	2.91E-05	9.89E-06	2.942331	0.0063
C(5)	-0.000976	0.000526	-1.855038	0.0738
C(6)	0.001776	0.000385	4.607138	0.0001
C(7)	0.011173	0.016892	0.661425	0.5136
C(8)	-0.002845	0.004552	-0.624993	0.5369

R-squared	0.566469	Mean dependent var	0.001299
Adjusted R-squared	0.461823	S.D. dependent var	0.035448
S.E. of regression	0.026005	Akaike info criterion	-4.272255
Sum squared resid	0.019611	Schwarz criterion	-3.923949
Log likelihood	87.03673	Hannan-Quinn criter.	-4.149461
F-statistic	5.413216	Durbin-Watson stat	2.047612
Prob(F-statistic)	0.000477		

APPENDIX 3.2: Normality, Serial Correlation and Hetereoskedasticity Tests

3.2.1 Normality Test



Series: Residuals	
Sample 1973 2009	
Observations 37	
Mean	-1.89e-17
Median	-0.000167
Maximum	0.070857
Minimum	-0.047339
Std. Dev.	0.023340
Skewness	0.469432
Kurtosis	4.028595
Jarque-Bera	2.990020
Probability	0.224246

3.2.2 Breusch-Godfrey Serial Correlation LM Test:

F-statistic	0.316295	Prob. F(1,28)	0.5783
Obs*R-squared	0.413293	Prob. Chi-Square(1)	0.5203

Test Equation:
Dependent Variable: RESID
Method: Least Squares
Date: 03/20/13 Time: 23:28
Sample: 1973 2009
Included observations: 37
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C(1)	0.016435	0.090369	0.181865	0.8570
C(2)	0.060024	0.178579	0.336122	0.7393
C(3)	-0.000374	0.005270	-0.070908	0.9440
C(4)	7.41E-07	1.01E-05	0.073411	0.9420
C(5)	6.37E-05	0.000545	0.117025	0.9077
C(6)	1.14E-05	0.000391	0.029228	0.9769
C(7)	-0.003887	0.018439	-0.210786	0.8346
C(8)	-0.000106	0.004611	-0.022962	0.9818
RESID(-1)	-0.180065	0.320171	-0.562401	0.5783

R-squared	0.011170	Mean dependent var	-1.89E-17
Adjusted R-squared	-0.271353	S.D. dependent var	0.023340
S.E. of regression	0.026317	Akaike info criterion	-4.229434
Sum squared resid	0.019392	Schwarz criterion	-3.837589
Log likelihood	87.24453	Hannan-Quinn criter.	-4.091291
F-statistic	0.039537	Durbin-Watson stat	1.888575
Prob(F-statistic)	0.999967		

3.2.3 Heteroskedasticity Test: Breusch-Pagan-Godfrey

F-statistic	0.915067	Prob. F(12,24)	0.5470
Obs*R-squared	11.61464	Prob. Chi-Square(12)	0.4771
Scaled explained SS	10.80463	Prob. Chi-Square(12)	0.5457

Test Equation:
Dependent Variable: RESID^2
Method: Least Squares
Date: 03/20/13 Time: 23:28
Sample: 1973 2009
Included observations: 37

Variable	Coefficient	Std. Error	t-Statistic	Prob.
C	0.012738	0.015983	0.797026	0.4333
$\ln CO_2(-1)$	-0.003979	0.007437	-0.535060	0.5975
lnY(-1)	-0.000398	0.000179	-2.221287	0.0360
lnW(-1)	7.65E-07	3.32E-07	2.303080	0.0302
lnTO(-1)	3.19E-05	2.05E-05	1.557285	0.1325
lnEC(-1)	-1.23E-05	1.60E-05	-0.765442	0.4515
lnURBAN(-1)	-0.000381	0.000673	-0.565572	0.5769
$\ln CO_2(-2)$	0.000827	0.007865	0.105098	0.9172
lnY(-2)	0.000420	0.000249	1.685226	0.1049
lnW(-2)	-8.10E-07	4.78E-07	-1.693395	0.1033
lnTO(-2)	4.08E-06	2.07E-05	0.197288	0.8453
lnEC(-2)	-2.48E-05	2.20E-05	-1.125272	0.2716
lnURBAN(-2)	-0.000136	0.000739	-0.183824	0.8557

R-squared	0.313909	Mean dependent var	0.000530
Adjusted R-squared	-0.029136	S.D. dependent var	0.000935
S.E. of regression	0.000949	Akaike info criterion	-10.81320
Sum squared resid	2.16E-05	Schwarz criterion	-10.24720
Log likelihood	213.0441	Hannan-Quinn criter.	-10.61366
F-statistic	0.915067	Durbin-Watson stat	2.135470
Prob(F-statistic)	0.546985		

APPENDIX 4: Results of the Pairwise Granger Causality Tests

Pairwise Granger Causality Tests
Date: 04/16/13 Time: 08:26
Sample: 1971 2009
Lags: 1

Null Hypothesis:	Obs	F-Statistic	Prob.
DlnY does not Granger Cause DlnCO$_2$	37	0.06190	0.8050
DlnCO$_2$ does not Granger Cause DlnY		0.00307	0.9562
DlnTO does not Granger Cause DlnCO$_2$	37	0.22602	0.6375
DlnCO$_2$ does not Granger Cause DlnTO		0.53843	0.4681
DlnURBAN does not Granger Cause DlnCO$_2$	37	0.00287	0.9576
DlnCO$_2$ does not Granger Cause DlnURBAN		1.26947	0.2678
DlnEC does not Granger Cause DlnCO$_2$	37	11.0536	0.0021
DlnCO$_2$ does not Granger Cause DlnEC		0.61656	0.4378
DlnTO does not Granger Cause DlnY	37	0.00224	0.9625
DlnY does not Granger Cause DlnTO		0.31712	0.5770
DlnURBAN does not Granger Cause DlnY	37	1.82395	0.1858
DlnY does not Granger Cause DlnURBAN		0.04970	0.8249
DlnEC does not Granger Cause DlnY	37	0.71478	0.4038
DlnY does not Granger Cause DlnEC		1.26532	0.2685
DlnURBAN does not Granger Cause DlnTO	37	0.07482	0.7861
DlnTO does not Granger Cause DlnURBAN		0.74782	0.3932
DlnEC does not Granger Cause DlnTO	37	0.05616	0.8141
DlnTO does not Granger Cause DlnEC		3.14224	0.0852
DlnEC does not Granger Cause DlnURBAN	37	0.76158	0.3890
DlnURBAN does not Granger Cause DlnEC		0.21360	0.6469

APPENDIX 5: Statistics of Variables Used

	lnCO_2	ln$Y$	ln$W$	lnTO	lnEC	ln$URBAN$
Mean	0.29785	252.4562	65162.33	52.68607	371.3003	4.013684
Median	0.289617	246.1978	60613.38	42.72816	368.9506	4.093773
Maximum	0.421717	341.5523	116658	116.0484	416.4284	5.116955
Minimum	0.207151	188.1487	35399.92	6.320343	304.9536	2.369379
Std. Dev.	0.053004	38.28531	20140.8	29.93133	25.6088	0.705382
Skewness	0.527335	0.510981	0.805725	0.436242	-0.366578	-0.782982
Kurtosis	2.529699	2.620168	3.056809	2.186701	3.086359	2.913234
Jarque-Bera	2.166956	1.931603	4.225002	2.311861	0.885586	3.997129
Probability	0.338417	0.380678	0.120935	0.314764	0.64224	0.13553
Sum	11.61616	9845.793	2541331	2054.757	14480.71	156.5337
Sum Sq. Dev.	0.106757	55699.08	1.54E+10	34043.61	24920.81	18.90742
Observations	39	39	39	39	39	39

APPENDIX 6: Data Used For Study

YEAR	CO_2	*Y*	*W*	*TO*	*URBAN*	*EC*
1971	0.257599264	301.3660271	90821.48227	35.9968011	3.355710213	336.2506061
1972	0.264390714	285.6461311	81593.71222	35.91674444	3.579417995	345.7254078
1973	0.26232628	285.5432776	81534.96339	37.8441691	3.615676523	356.6037102
1974	0.303054849	297.0348396	88229.69594	40.12789342	3.412876286	364.540812
1975	0.27679898	254.067206	64550.14518	37.78345835	3.075257112	368.8183303
1976	0.240624455	240.3416727	57764.11965	31.75661225	2.694924222	361.9450782
1977	0.291843072	241.7066401	58422.09986	22.04435973	2.412145852	377.7772617
1978	0.28392725	257.9161617	66520.74644	18.04623085	2.369379147	370.7233761
1979	0.249295737	246.6444817	60833.50037	22.39387783	2.640887756	366.5893311
1980	0.234334379	241.9462395	58537.98279	17.62111479	3.108021655	368.3588356
1981	0.270965241	226.7589089	51419.60276	10.07903451	4.020317714	374.3105442
1982	0.261822085	204.1828801	41690.64854	6.320343068	4.403479776	372.2818069
1983	0.303662902	188.1486653	35399.92027	11.54489874	4.586779606	304.9536353
1984	0.207150554	197.4867748	39001.02623	18.81463522	4.518037633	314.8779609
1985	0.258388599	200.9364455	40375.45511	24.24385285	4.291284548	338.1147323
1986	0.229776302	205.1677706	42093.81411	36.71168142	5.116955427	341.255107
1987	0.24090493	209.0656817	43708.45926	45.84816495	4.889304597	359.6282727

1988	0.24628214	214.965181	46210.02903	42.2455037	4.737886597	342.5583317
1989	0.232362435	219.9076008	48359.3529	41.08584313	4.691792491	359.5587433
1990	0.265727961	221.0716696	48872.68308	42.72816153	4.711451214	357.6613649
1991	0.265816617	226.2823318	51203.69368	42.4883211	4.826670272	359.821776
1992	0.261629984	228.4587968	52193.42185	45.99356699	4.818504263	362.2074871
1993	0.289616803	232.8512761	54219.7168	56.66913481	4.763284413	368.9265942
1994	0.306342822	234.0064503	54759.0188	62.02115067	4.646874684	373.4656087
1995	0.319302913	237.2935875	56308.24665	57.42309273	4.494946353	380.7331701
1996	0.33031849	242.0582959	58592.21861	72.20494573	4.394697501	384.0595405
1997	0.358171854	246.197848	60613.38038	85.40183999	4.263259188	393.8165526
1998	0.350229332	251.7652913	63385.76189	80.59954489	4.171794157	403.3925068
1999	0.349934568	256.7399526	65915.40325	81.70510323	4.131662964	406.0697567
2000	0.328136927	259.9906944	67595.16119	116.0484325	4.126129678	403.6537547
2001	0.352462082	263.9615458	69675.69764	110.0458546	4.093773115	416.4283642
2002	0.368625879	269.2285553	72484.01497	97.48924392	4.085422859	414.6891865
2003	0.368641113	276.4051992	76399.83413	97.28714491	4.070956544	397.4845442
2004	0.344477209	284.8491549	81139.04103	99.67033448	4.04578262	391.3658064
2005	0.321458473	294.4080169	86676.0804	98.17151411	4.012584306	380.2490651
2006	0.418957062	305.7511071	93483.73948	65.92300977	3.888763232	408.7335924
2007	0.421716892	317.7363633	100956.3966	65.35408695	3.859135118	399.0817264
2008	0.366634176	336.3518402	113132.5604	69.51414901	3.824309565	385.0493566
2009	0.312453173	341.5522907	116657.9673	71.59283854	3.783535231	368.9505827

Source: World Bank's World Development Indicators (2012)

Note: *CO_2* represents carbon dioxide emissions per capita, *Y* real GDP per capita, *W* real GDP per capita squared, *TO* (% of GDP), *EC* energy use per capita and *URBAN* urban population growth rate. *W* is calculated by squaring *Y*.