TRADE-INDUCED ENVIRONMENTAL EFFECTS: THE ROLE OF FACTOR ENDOWMENT AND ENVIRONMENTAL REGULATION

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THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF MPHIL ECONOMICS DEGREE

JULY, 2017

DECLARATION

This is to certify that this thesis is the result of research undertaken by Angela Cindy Emefa Mensah towards the award of Master of Philosophy Degree in Economics at the Department of Economics, University of Ghana, Legon.

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DEDICATION

This thesis is dedicated to my loving mother, Peace Adamah and my siblings for their care, love and support for dreams.

ACKNOWLEDGEMENT

I am Grateful to God Almighty for His sustenance and Grace which has brought me this far. My warmest appreciation goes to my mother, Peace Adamah and Rev. Father Abaiku William Apprey for being that voice of encouragement in my academic pursuit. I am profoundly grateful to my supervisors, Dr. D. K. Twerefou and Mr. K. Tsikata for their time, guidance and suggestions that have made this work a success.

ACRONYMS

EKC	Environmental Kuznets Curve
EIA	U.S. Energy Information Administration
EPA	U.S. Environmental Protection Agency
GHG	Greenhouse gas
GMM	Generalized Method of Moment
IEA	International Energy Agency
IPCC	Intergovernmental Panel on Climate Change
OECD	Organisation for Economic Co-operation and Development
R&D	Research and Development
SDGs	Sustainable Development Goals
UNCTAD	United Nations Conference on Trade and Development
UNDG	United Nation Development Group
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNIDO	United Nations Industrial Development Organization

ABSTRACT

This study investigates the effect of economic growth and international trade openness on carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O) and the fluorinated gases (F-gases) emissions. It also examines whether the trade-induced emissions originate from countries' relative factor endowment or/and environmental regulations using panel data for 18 African countries, spanning from 1990 to 2014 and the Generalized Method of Moment (GMM) estimation technique.

The results indicate that with the exception of CO_2 where income negatively and significantly impacted on emissions, income did not significantly explain emission of the other gases. With the exception of CH_4whose trade impact appears to be inconclusive, trade impacted positively on emission of all the other gases under consideration, signifying that increased trade openness is detrimental to the environmental quality. A notable conclusion is that the trade-induced pollutions originated from factor endowment effect and not the environmental regulation effect.

It is therefore recommended that countries in Africa should strengthen existing institutions in charge of ensuring environmental protection and enforce stricter environmental regulations, which will require polluting firms to pay abatement cost. Also, to environmentally sustain income growth, modification should be made to input compositions that will ensure efficient energy use.

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CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

The environmental impact of international trade has been an issue of much debate in recent decades, especially for emerging and developing regions like Africa, due to the increase emission associated with the environmentally unsustainable production process in these resource-based economies. This pollution growth has heightened global concern for climate change. Such that September 2015, saw the adoption of the 17 Sustainable Development Goals (SDGs) to be accomplished by 2030, among which is the crucial call to *"take urgent action to combat climate change and its impacts"* (SDG 13) (United Nations Environment Programme, 2016).

According to the Intergovernmental Panel on Climate Change (IPCC), the unprecedented increase in anthropogenic greenhouse gas (GHG) emissions in recent years is mainly driven by economic and population growth (IPCC, 2014). The IPCC (2014) reported that more than half of the average global temperature observed from 1951 to 2010 was caused by these anthropogenic gases; carbon dioxide (CO_2), methane (CH_4), nitrogen oxide (N_2O) and the fluorinated gases (F-gases). Thus, economic growth which is meant to be a measure of a country's improvement may turn to harm the environment if not well managed (Vutha & Jalilian, 2008). Despite the threat posed by economic growth anchored on coal consumption, Energy Information Administration (EIA)(2016) noted that coal still remains the second largest source of energy worldwide, next to petroleum. This source of energy is an important factor of production which is the engine of international trade. As such, international trade compositions practically depict a country's energy consumption (Agras & Chapman, 1999).

The idea of international (free) trade, dated far back as the times of Adam Smith and other proponent like David Ricardo, is a set of economic relationship between countries, in which members are encouraged to concentrate their effort in the production of commodities for which they have comparative advantage. The proponents argue that free trade when conducted on bases of comparative advantage will increase production, income, ensure efficient allocation of resources, and increase consumption.

This has long been confirmed by a large body of literature supporting the idea of a strong favourable relationship between economic growth and free trade (Edwards 1992; Sachs & Warner 1995; Krueger 1997; Frankel & Romer , 1999). A classic example is the East Asian countries during the 1960s and 1970s that opened up trade and adopted export-led growth policies which impel their growth, moving them from raw material exporting countries to exporters of dynamic high technology products and increasing their competitiveness in the global market (Hammouda, 2004). Around the same period (1960s and 70s) African countries were implementing inward looking trade policies which pushed most Africa countries to the brink of collapse. After the failure of the restrictive trade policy, many Africa countries persuaded greater external trade openness. And just about the mid-1990s, Africa's real GDP growth took a giant leap from the negative to 2% per annum and to 5% in the first decades of the 21st century, despite the economic fluctuation in the 2000s (Mullings & Mahabir, 2004). Trade as a share of GDP increased from 40% in 1993 to 60% in 2007, fell only fairly during the global financial crises and rebound in 2010. Between the periods of 2000 to 2010, Africa's export increased annually at an average of 15% (Mullings & Mahabir, 2004) .

These statistics have continuously deepened the tariff liberalization effort of African countries such that the United Nations Conference on Trade and Development (UNCTAD) (2013) reported a significant reduction in average tariff applied on imported goods by most developing countries as at 2012. Average tariff applied were below 10 percent. However, some countries in the Sub-Saharan African region still maintained restrictive tariff policy relatively above 10 percent between 2002 and 2012, but comparatively the rates are low (UNCTAD, 2013). This is reflective of the overall expansion in market access conditions. Undoubtedly, both "zero most-favoured-nations" (MFN) and "preferential duty-free access" have increased the share of developing countries in world trade. According to the World Trade Organisation (2015), trade within the region has also increase from 10 percent in 1995 to 18 percent of the region's total exports in 2014. Aside increasing volumes of trade, greater trade openness encourage foreign inflows, promotes entrepreneurship among the private individuals/firms, encourage learning by doing and foster new knowledge and technology development which are essential for high productivity and economic growth (Mullings & Mahabir, 2004).

However, the argument for protection of infant industries (Bardhan, 1970)has been the main strain on trade openness. This hypothesis maintains that if infant industries are not protected, they may not survive the global competition, thus leading to income divergence. UNCTAD (2013) also maintain that, some tariff imposition may be relevant to protect the agricultural sector of developing countries. However, empirical evidence has shown that economy openness rather promote convergence (Sachs & Warner, 1995) and thus lead to increase industrialization. Contrary to the popular infant industry argument, Dodzin & Vamvakidis (1999) also found increased

trade openness during 1970-1995 to have increased industrial production in developing agrarian economies.

However, there is a growing concern for the environmental impact of international trade and the likelihood of pollution intensive industries moving to developing countries. Considering that many African countries, now more than ever, are concerned with trade liberalization to boost their economies, there is the tendency to specialize in pollution intensive goods where their comparative advantage lies. This may be detrimental to the environment (Dean, 1992a; IPCC, 2001) and climate change. As mentioned in United Nations Industrial Development Organization (UNIDO) report for 2006, Africa countries perform poorly when it comes to ensuring environmental sustainability due to weak environmental policies. Moreover, most of Africa's traditional productions are environmentally unsustainable. Those industrial processes that require large machines with heavy energy use are typically pollution intensive (Cole, Elliot, & Shimamoto, 2003). Given that tariffs are not effective at restricting trade in most energy and raw material sectors (UNCTAD, 2013) and with the kind of energy used by Africa's industries, greenhouse gas emission could become a major issue of concern (UNIDO, 2006).

Moreover, being an agriculture based region, Africa grows largely on importation of manufactured products (automobiles, fertilizer, chemicals and so on) and exports products like gold, timber, palm oil, tin, coffee, rubber, and cotton. Increasing trade in these primary products require the destruction of more greenery. As mentioned in the Kyoto Protocol, agricultural practices in the form of soil and manure management, burning of field for cultivation, deforestation, and rice cultivation constitute significant sources of carbon dioxide, nitrous oxide and methane emission. In fact, the International Energy Agency (IEA) (2012) reported that

agriculture's share of world anthropogenic gas emissions was estimated at 70 percent of nitrous oxide as at 2010, 50 percent of methane and 20 percent of carbon dioxide (see, Isermann, 1994). The greatest f-gas emission comes from the leakages in used imported automobiles, fridges and factory machines.

In response to the on-going debate, two positions are invoked in literature when it comes to explaining the interrelationship between international trade and the environment. First, is that trade is harmful to the environment (see, Managi, 2004), due to the quest to improve income through trade. The second proposition is that, trade is good for the environment (Antweiler, et al., 2001), as it is believed that the income is a preconditions for improving the environment (Bhagawati, 1993).

Therefore, in trying to understand the trade and environment dynamics; whether it's harmful or beneficial, two levels of overlapping relationship need to be understood. The first is the interrelationship based on comparative advantage resulting from factor endowment. This means countries will concentrate production on commodities that make use of their abundant factor (capital, labour or natural resources) or those that they can cheaply produce. This is likely to lead to pollution of environment, due to resource extraction processes like mining and crops cultivation. The second interrelationship between trade-environment comes as a result of the comparative advantage that national trade policy poses. National environmental policies such as, environment tax, prohibition and subsidies can influence competiveness of domestic industries in international trade. The power of interest groups to lobby government or international agencies for or against these barriers or incentives would have implication for the environment.

1.2 Statement of the Problem

Global climate change continues to threaten lives and property, thus combating climate change is a matter of urgency. There have been many studies that sought to explain the relationship between trade openness and the environment and their findings have been inconclusive. However, one thing that is certain is that, as power plants and industry boilers continue to combust fossil fuel, CO_2 emission (so are the other traces greenhouse gases) will increase and global warming is inevitable. Andersson, Quigley & Wilhelmsson (2009) in an attempt to analyse the emission in China's transport sector focused on export and found that international trade plays a significant role in the level of CO_2 emission in China. China's chase after economic growth came at a cost. Among the 25 most polluted cities in the world, seventeen could be found in China and premature deaths resulting from air pollution was estimated at 3000000 people each year (Wang, 2007).

A similar fate may befall Africa, considering it to be a developing region that has comparative advantage in resource-based industries due to its laxer environmental regulations. According to the Organisation for Economic Co-operation and Development (OECD) (2011), these resource-based industries tend to be highly pollution intensive. Cole (2003) posited that as Africa countries tend to specialize in pollution intensive output, it may give rise to a situation where the North relies on the South for the provision of pollution intensive output, while the North will specialize in the production of environmentally clean output. This supposition corroborates Managi's (2004) argument that trade is bad for the environment. However, Cole and Elliot (2003a) and Antweiler et al (2001), found evidence that greater trade openness reduces SO_2 emission. But Cole and Elliot (2003a) were quick to add that CO_2 and nitrogen oxide is likely to increase with increase trade openness.

In the midst of these inconclusive arguments, it is also not well established if trade-induced emissions originate from differences in countries' comparative advantage due to the Capital Labour Effects and/or Environmental Regulation Effect. Cole and Elliott (2003a) extended Antweiler et al (2001) to investigate the source of trade-induced pollution for SO_2, NO_x, CO_2 and biochemical oxygen demand (BOD) but specific results for Africa are lacking. Moreover, works on this topic, such as Cole and Elliott's (2003a), did not take into accounts the specific situation in Africa and uses the Generalized Least Square estimation technique which suffers from omitted variable bias, spatial autocorrelation, spatial heterogeneity, spatial dependence and is unable to correct for endogeneity, especially when sets of spatial units (like continents, states and countries) are present in the data (Arbia & Piras, 2005).

Thus, adopting dynamic econometric techniques and using CO_2, N_2O, CH_4, and total F-gases as proxy for environmental quality, this study attempts to examine whether income and trade openness drives GHG emission. Also, to establish if the trade-induced emissions originate due to differences in countries' comparative advantage captured in the form of capital-labour endowments or/and environmental regulations effects.

1.3 Research Questions

The following questions are posed to guide the study.

1. Does environment quality improve with increase in income?
2. Does trade openness directly drive environmental deterioration?
3. Does trade-induced emissions originates from differences in country's factor endowment?

4. Do trade-induced emissions originate from differences in country's environmental regulations?

1.4 Objectives of the Study

The primary purpose of this study is to assess the trade-induced environmental effects paying particular attention to the role capital-labour ratio and environmental regulation. Specifically, the study sought to find out whether:

1. Environmental quality improves when income increases.
2. Trade openness directly drives the deterioration of environmental quality.
3. Trade-induced emission originates from differences in country's factor endowment.
4. Trade-induced emission originates from differences in country's environmental regulations.

1.5 Research Hypothesis

Having gone through the above arguments and suppositions in literature, this study formulates three hypotheses, which are relevant to explaining the trade-environment dynamics in Africa. They are as follow:

1. **Null Hypothesis:** There is no relationship between income growth and GHG emissions.

   Alternative Hypothesis: There is a relationship between income growth and GHG emissions.
2. **Null Hypothesis:** There is no relationship between trade openness and GHG emissions.

Alternative Hypothesis: There is a relationship between trade openness and GHG emissions.

3. **Null Hypothesis:** Lower capital-labour ratio discourages trade-induced GHG emissions.

   Alternative Hypothesis: Lower capital-labour ratio encourages trade-induced GHG emissions.

4. **Null Hypothesis:** The laxity of environmental regulations encourages trade-induced GHG emissions.

   Alternative Hypothesis: The laxity of environmental regulations does not encourage trade-induced GHG emissions.

1.6 Significance of the Study

Considering that trade is the backbone of every economy, the findings of this research provide a guide for new directions of sustainable production and trading activities across Africa. The outcome of this study is expected to reflect the true state of the trade-pollution effect for Africa. Because, it is by far the first study of this nature that have accounted for the country heterogeneity specific to Africa. The outcome of the study is therefore expected to stimulate stakeholders to pay attention to Africa's environmental quality.

Specifically, if found out that environmental regulations promote emissions or are irresponsive toward it, then state institutions in charge of environmental protection ought to be strengthened. This will also suggest to the civil society organisations to mount pressure on government to take actions toward curbing emissions. This will help policy makers in streamlining the kind of trade agreement that countries in the region sign to. This study contributes to literature by validating Cole and Elliot

finding on CO_2; and determining further if these results hold altogether for the four GHGs and what that means for climate change in Africa.

1.7 Organisation of the Study

This chapter focuses on the background to the research, the problem statement, the purpose of the study, research questions, and a brief outline of the research hypothesis and the significant of the study. Chapter two reviews related literature on the topic. The third chapter deals with the methods or the research approach used. Chapter four presents results and discussions of econometric estimations. The last chapter, chapter five, comprises the summary, conclusion and recommendations of the study.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction

There is an overwhelming body researches linking trade and the environment but the pollution impact of trade on the environment is met with a lot of controversy subjected to lots of complexities and ambiguities. This work focuses on the origin of international trade induced emissions (be it from factor endowment or/and environmental regulation effectiveness) and how it influences policy responsiveness toward climate change in the long run. Hence, this chapter attempts to address the trade and environment interrelationship by looking at the theoretical considerations and the empirical evidences.

2.2 Theoretical Review

In line with the debate about environmental pollution effect of increasing global economic activities, many researchers have reexamined the line between environmental pollution and international trade. These investigations take their theoretical root from the traditional income-pollution interrelationship (largely called the Environmental Kuznets Curve (EKC)). For the purpose of this study; we draw on the EKC to explain the trade-pollution interrelationship.

2.2.1 Income and the Environment (EKC)

As first suggested by Grossman and Krueger (1991) (as cited in Panayotou,1993; Dinda, 2004; Gallagher & Ackerman, 2000), the EKC have seen some level of nobility and attention from researchers and policy analysts over the

years, since the adoption of the hypothesis in the works of World Bank (1992) and Grossman and Krueger (1995). “The view that greater economic activity inevitably hurts the environment is based on static assumptions about technology, tastes and environmental investment” (World Bank, 1992; p 38) hence “as incomes rise, the demand for improvements in environmental quality will increase, as will the resources available for investment” (p 39). It is believed that awareness about environmental damage is quite negligible at the initial stage and environmentally sustainable production processes are not readily available or are not adhere to.

The effects of income growth on environmental quality can be explained through three channels, *the scale effect, tecnological or technique effects and composition effect*.This is probably the first factor invoked in literature to explain the EKC. The scale effect basically explains the increase in emissions resulting from increasing levels of economic activity, holding all other factors constant. It simply captures the increasing depletion of natural resources as output (GDP) increases resulting in increased emission or environmental degradation. The output growth, increases the volumes of trade in export through the scale effect which spurs GDP and eventually translate into pollution (Antweiler et al, 2001; Dinda, 2004). That is because, countries engaging in trade increase production by depleting natural resources. Assuming production techniques and product mix remain the same, higher economic activities will inextricably result in proportionately higher levels of pollution.

As a country’s income grows, any observable changes in emission arising from industries’ composition is explained by the *composition effect.*It refers to changes in emission resulting from changes in the relative shares of different commodities in a country’s aggregate production. The composition effect ascribes a

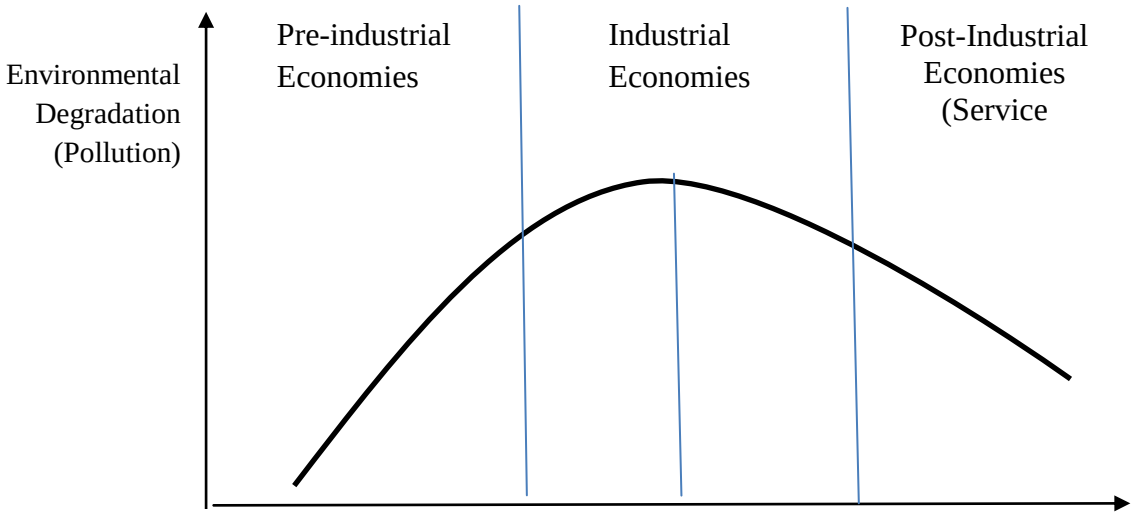
positive or negative effect to the composition of a country's production depending on the level of changes in product-mix. As GDP increases economy's structural changes and production activities turn to be cleaner. The composition effect, which manifast it self in the form of stringent environmental regulation as income increase, is able to transition the EKC toward the declining phase, if income growth can sustainably change product mix. In other words, the composition effect determines the direction of emission growth. Failure to structurally change production in response to rising income would result in increasing levels of emission.

Finally, the *technique effect* depicts channels through which income growth affect the rate of pollution from households and industry. The technological effect is manifested in form of improved and new technologies in production. It is believed that as per capita increases, people would value quality environment more and would be willing to pay for it and invest in cleaner technology which in turn reduces emissions. The technique effect stipulates that as countries gets richer; they would be able to increase spending on R & D (Komen, Gerking , & Folmer, 1997), which replaces pollution intensive methods and obsolete techniques for cleaner technologies. Similarly, political regulatory climate of the environmental protection policies become more effective. As such, the technique effect is responsible for the falling part of the inverted U-shaped curve. Therefore, GDP growth improve the environmental quality through both the composition and technique effect as a result of adoption of stricter environment regulations and investment in R&D for innovative production processes.

According to some researchers (like Panayotou, 1993), the income-pollution relationship is due to up-gradation from economic structural adjustment. The structural adjustment hypothesis posits that economic development goes through three

stages; preliminary, rapid-development and high-grade (Panayotou, 1993; Stern, 2004). In other words, industrial structure upgrade starts from the agro-base to highly pollution industries, then to information-based/service industry. The third phase of information concentrated industries amplifies the quality of environment. Such that, at low level of income, countries can only afford to use pollution intensive technique but once income rise above the threshold point, cleaner technique are adopted which reduces the level of environmental pollution. In other words, environmental pollution rises with increases in income until it reaches a threshold point beyond which pollution begins to fall with growing levels of income. This income-pollution dichotomy is depicted in the inverted-U shaped curve in figure 1.

Figure 1: Environmental Kuznets Curve



Source: Panayotou (1993)

As seen in figure 1, accelerating economic development, at initial stages, would increase resource extraction and agriculture production to the point where resource regeneration falls short of depletion coupled with higher levels of waste generation (Dinda, 2004). But higher income levels in turn cause structural changes,

increases awareness of environmental damage, promote effective environmental regulations, encourage adoption of better technology (Dinda, 2004), which transitions the rising curve into its declining phase where environmental quality is improved. In other words, higher levels of development moves structural changes in the direction of industrialization or information-based economy and service, such that, the increasing demand for cleaner environment, and adoption of efficient techniques impel a reduction in pollution (Panayotou, 1993).

Throughout literature, the *income elasticity of enviromental quality demand* isinvoke as the main explainatory factor for the three channels to hold (see Dinda, 2004).Pollution will invariably fall with increasing levels of income in a society of rational consumers of quality environment. As such, EKC will hold when people's desire for cleaner environment is more than unitary. This elasticity is expected to drive the income-pollution relationship, in a manner that will cause pollution to reduce with increasing income, as peoples' willingness to pay for abatement increases. The elasticity of cleaner environment is assumed to be strong enough to transition the turning point of the EKC for an improved quality of the environment (Dinda, 2004). This premise, for EKC to hold only when the income elasticity of environmental quality is elastic, is a very delicate core. If this assumption breaks down, emission may either decrease or increase without bound with rising levels of income. It is, however, not clear the level of income at which this transition begins to take place or what accounts for the complete inverted U. But if higher income growth can be sustain then the EKC would hold (Stern, 2003).

Another argument that has been advanced in literature to explain the inverted U-shaped income-pollution relationship is *market mechanism*. In the first place, market mechanism should be *self-regulatory*. Self-regulatory market mechanism is

instrumental in shaping the EKC curve (Dinda, 2004). The World Bank's 1992 report put forward the argument for the establishment of self-regulatory market mechanism for tradable natural resources to protect the environment from the income-degradation responses associated with the scale effects. Unruh and Moomaw (1998) also alluded to the need for endogenous regulatory bodies for tradable resources. Market mechanisms, when strengthened pushes emerging economies to develop less polluting energy resources (Kadekodi & Agarwal, 1999).

*The Price mechanism*within the market also to a larger extent explain the income-pollution process. The initial stages of a country's development is driven by heavy reliance on the agriculture sector with is characterised by extraction and exploitation of natural resources. More often than not, the initial prices of these natural resources do not reflect their true values. But as markets develop in response to higher levels of economic growth, resources are efficiently used and pricing begins too take shape. Following from the basic demand theory, as prices/cost of natural resources extraction increase, demand is expected to fall. This will serve as a disincentive for exploitation thereby reducing environmental degradation. Price mechanism basically drives a wedge between exploitation and pollution leading to reduction in pollution from extraction (Dinda, 2004). Higher prices will promote the adoptation of more efficient technologies in exploitation which at large may prove to be less resources-intensive (Torras & Boyce, 1998). For example, the 1970's oil prices rise encouraged the need to sought for alternative energy sources of electricity production other than crude oil (Unruh & Moomaw, 1998). Hence, environment quality in transitioning economies is improved rapidly by the rising energy prices which serve as disincentive for actitivities that are energy-intensive (Nilsson, 1993; Vukina, et al., 1999). Moreover, when economies are recovering from market failure,

price mechanisms reallocate resources which may lead to improvement in environmental quality.

It is worth noting that price mechanism can relocate resources efficiently in the market if there is complete *market information accessibility.* Market mechanisms are efficient if product and process information is available. As such the level of market competitiveness depends on participants' knowlegde of production processes and product quality (Dinda, 2004). Environmental quality can be influence by the level of accessibility to market information (Bimonte, 2002). Social intervention policies also rely on market information response to deal with environmental quality issues.

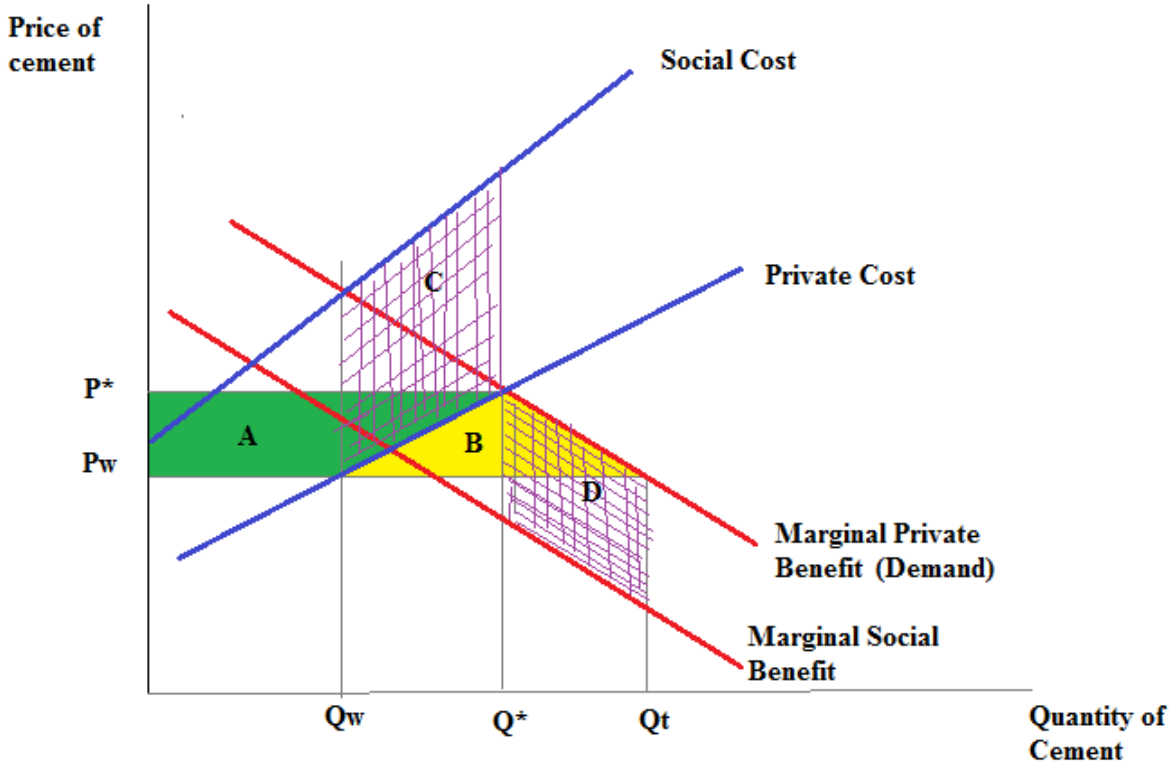
This, therefore, emphasis the need for active *economic agents*within the market. Economic agents (such as households, firms, government and non-governmental organisations, policy makers and other units in the market) are also very instrumental in determining the income-environmental quality relationships (Dinda, 2004). Civil society groups and other market participants could serve as pressure groups toward fostering a cleaner environment. The inclussion of Civil Society Organisations in the fight against emission abatement in Africa is crucial, considering the supposition of Owoye & Bissessar (2012), that governance throughtout the region is of low quality and oftentimes describe as being "bad". According to the United Nation Development Group (UNDG), there are strong voices advocating for the full participation of civil societies in the design of the post-2015 SDGs with the aim of extablishing national systems that are funtional. These "voices" include national and local decision-makers, the private sector, civil societies, young people and children, gays, lesbian, bisexual, transgender, indigenous people, homeless and displaced people, trade unions, farmers, prison inmates and gang members

(UNDG, 2013). According to the United Nations Development Program's *"A Million Voice"* report (UNDP, 2014), the global consultation process on the post-2015 agenda saw the emergence of the "voices" in a collaborative effort to incorporate the views of all interest groups and increase awareness toward sustainable development. Public awareness of heavy polluting product may cause a change in consumption pattern, if consumers are determined to protect the environment. A similar example of the influence of interest groups on the EKC can be found in the works of Dasgupta et al (2001) and Gupta and Goldar (2003) who provided evidence that capital markets aid in promoting cleaner products. Basically capital markets that are determined to protecting the environment will not advance loans or invest in polluting sectors.

2.2.2 International Trade and the Environment

The clearer picture of our understanding of the interrelatedness between international trade and the environment can be analyzed using economic theory. The Ricardian theorem postulated that, the relative prices of commodities determine the trade patterns and comparative advantage of trading countries. According to the Ricardian theory, the price difference between countries is due to differences in technology (Xing & Kolstad, 1996). The comparative advantage emphasis by the Ricardian theory state that countries trading together should specialize in the commodities they can most efficiently produce. However, the environmental externality associated with production and consumption of these goods is not captured in this basic theory of comparative advantage (Harris, 2004). Figure 2 present the externality associated with production and consumption of cement; one of the major sources of carbon dioxide emission.

Figure 2: Gains and Losses from Cement



Source: Authors Sketch

The private cost of cement production is assumed to be the supply curve, while the private cost plus externalities form the social costs. P* and Q* are the autarky price and quantity produced respectively. In free trade, the word price is P_w, while Q_w is the domestic quantity produced and Q_t is total domestic consumption. This implies that (Q_t - Q_w) is the quantity imported.

In autarky, the domestic producers sell more cements (Q*), but when trade opened they sell less at the reduced world price. Therefore, the welfare loss to domestic producer is measured by the shaded area A. On the other hand, welfare of domestic consumers is improved as they can buy more at a reduced price. Consumption gain is measured with the shade regions A + B. The net gain from trade is given by putting together both producers' welfare lose and consumers' welfare; (A

+ B) – A = B. However, it will be dubious to conclude that there are gains from trade without taking into consideration the environmental externalities or pollution effects.

As domestic producers reduce production in response to the low world price, environmental pollution is reduced. This reduction of cost to the environment is captured by cross-shaded area C. This structural change in production in a way explains the composition effect hypothesized by the EKC. However, if consumption does not fall with the declining level of domestic production, then it will result in displacement of pollution to exporting country. This clearly explains a phenomenon where pollution is exported between countries as a result of trade liberalisation. Ghana's increasing importation of cement from Nigeria is an example of such pollution shifting. In essence, if consumption pattern remain unchanged and production process are not updated, then polluting industries may be displaced from one country to another and regional or global emission will continue to increase. Alternatively, if the externality originates from consumption, then increasing consumption as a result of trade openness will increase pollution. In other words, the cost to environment increases with trade openness. This cost is captured by the cross-shaded region D.

As shown in figure 2, international trade liberalization results in relative price changes – by removal of tariff and non-tariff barriers – relative prices of import-competing goods are reduce. This could cause disturbances in other productive sectors of the economy – moving labour and capital from the contracting sectors to expanding sector. This reallocation of resources may lower or reduce a country's emission growth depending on pollution intensity of the expanding sectors. This pollutions become more profound if environmental cost are not paid for by polluting industries. That is, if environment is considered free input in the production process.

It is however; clear that free trade has to internalize environmental cost, in such a way as to regulate the polluting industries. If this requires polluting industries to pay environmental cost, then polluting industries may change the prices of goods produced, in order to internalize the externalities. From figure 2, this form of abatement cost from the consumer side is the cross-shaded region D. Failure to cut down production in figure 2, producers would have to bear the reduce prices and pay the environmental cost of C. This lowers their natural capacity to pollute. In a real case, the U.S. industries spend $101.7 billion as the total pollution abatement capital expenditure in 1991 (Xing & Kolstad, 1996). Environmental cost of this magnitude will definitely affect a country's comparative advantage. The comparative advantage is driven by two forces: *the factor endowment and pollution haven pressure* (De Melo & Mathys, 2010).

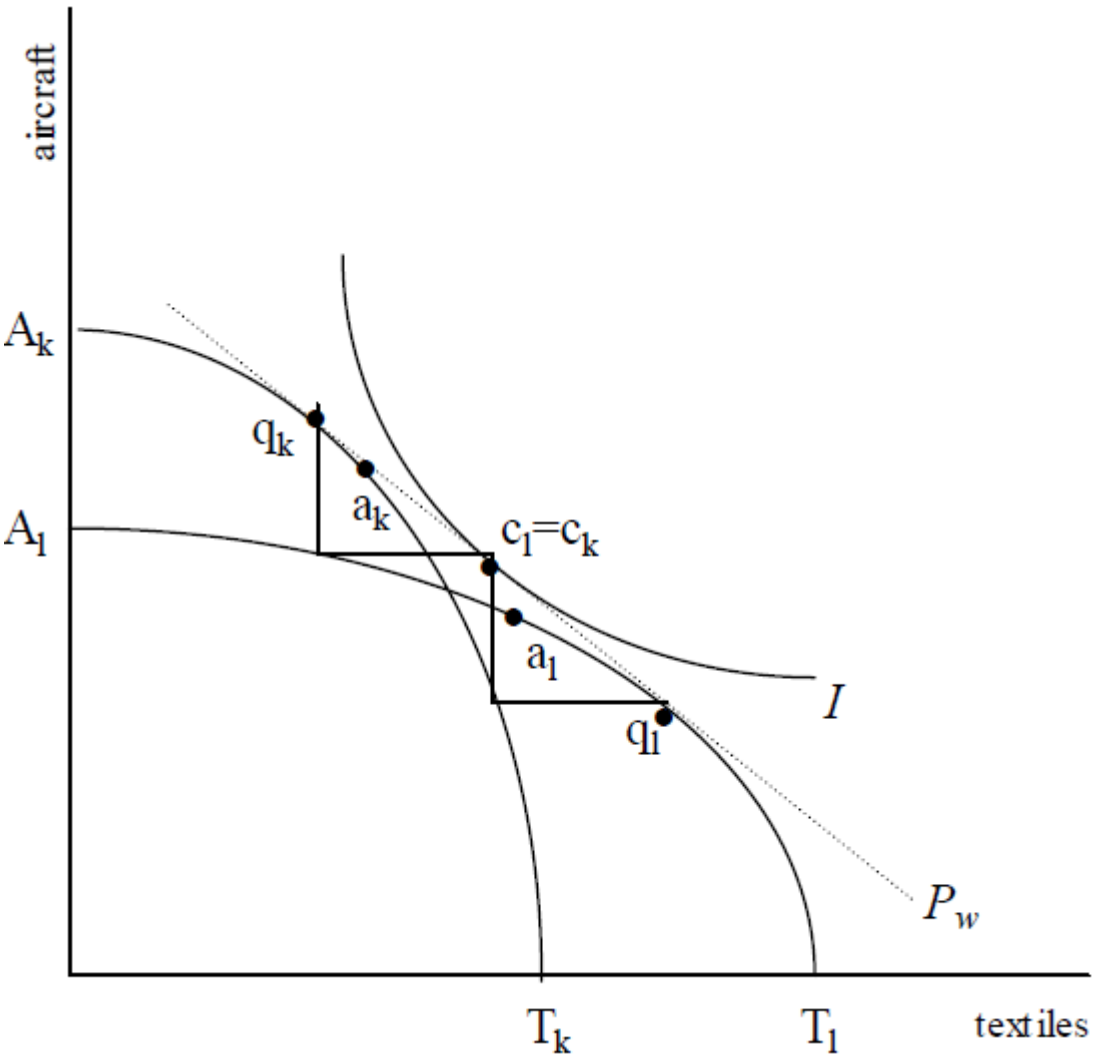
2.2.2.1 Factor Endowment Theory

The modern theory of international trade is what is known as the factor endowment theory and subsequently the Hecksher-Ohlin-Samuelson (HOS) model of trade. It is assumed that there are two countries endowed with two factors of production that are producing two commodities. Unlike the Ricardian model where technology differences matters, each country in this model is assumed to share identical technologies in the production of the two commodities and have identical consumption preferences of the two commodities produced. However, producing each goods require different factor intensities. For example, aircraft manufacturing will require more capital per unit of labour than what is require in a textile industry. In autarky, the price definition of factor abundance require that the wage rental ratio must be higher in the country with abundant capital whereas, the wage rental must be

lower in the country with labour abundant (Feenstra, 2004). This is depicted by the production functions of each of the two commodities in figure 3, which also shows constant returns to scale and diminishing returns to each of the two inputs.

Each production factor is assumed to be immobile across countries but can be allocated freely between industries. The differential in factor prices, therefore, offsets the relative physical factor abundance. For example, the higher labour requirement in a textile industry make producing textile in the capital abundant country relatively costly.

Figure 3: Factor Proportion Analysis



Unlike the single-factor Ricardian model where the autarky price ratio is the inverse of the labour productivity ratio, the Hecksher-Ohlin model demonstrate that the autarky price of commodity that intensely use abundant factor will be lower in factor abundant country relative to the other country (Feenstra, 2004). As shown in Figure 3, for a given capital-labour ratio, the production possibilities frontier of the capital abundant country is denoted by AkTk and that of labour abundant country AlTl. Supposing that aircraft production requires more capital relative to labour, then the capital intensive country will find it more beneficial devoting more of its resources to the production of aircraft. The autarky prices in each country are reflected by the indifference curves, which also reflect identical and homothetic preferences of the countries. As expected the relative price of aircraft in terms of textiles is lower in the capital-abundant country, as compare to the relative price in the labour-abundant country. In essence, the country with AkTk reaches a higher indifference curve when it allocates more of its resources to the production of aircraft.

By extension, when trade opens countries would export commodities that uses intensely their relative abundant factor. This proposition is what has come to be known as the Hecksher-Ohlin theorem. The price differential suggested in this proposition implicitly presents a situation where no trade will occur between the countries when autarky prices are identical (Feenstra, 2004). In a free trade where preferences are identical and technologies are the same in both countries, the two countries would want to consume equally at the world price, thereby establishing a new equilibrium at $C_I = C_k$. In this case, the labour abundant country gain from trade by exporting textile at a relatively higher world price and buying aircraft at the reduce world price, since it much more expensive for them to produce aircraft compare what is offer in the world trade. This constitutes a change in demand which will shift the

production frontier outward. Such that instead of producing at a_I, the labour abundant country now produce at q_I and consumes on a higher indifference curve C_I.

Aside the consumption gains from the free trade, countries become more specialized in the commodities that use their abundant factor, thereby resulting in efficiency gains for each country. It follows that, the greater the differences in the relative factor endowments of two country, the more likely they are to specialize in the commodities that make use of their abundant factor, thereby increasing the volume of trade among themselves. Intuitively, if the relative factor prices are lower, then the associated relative autarky price of the commodities that use the abundant factor will be lower. The reverse of this proposition holds.

However, if relative factor prices are equalized in both countries, then the capital-labour ratio used in the production of the two commodities (aircraft and textile) in both countries should be equal as well. This proposition is called the factor-price-equalization theorem, which states that as long as the two countries produce positive quantity of the two commodities under identical constant returns to scale, free trade in commodities will equalizes the relative factor prices by equalizing relative prices of commodities (Feenstra, 2004). This follows that when trade opens increasing demand for the two commodities, the capital abundant country would specialize in production of aircraft whereas the labour abundant country specialize in textile. Given that capital-intensive productions emit more pollution, if the price mechanism does not completely internalize the externalities, pollution will invariably increase.

2.2.2.2 Pollution Haven Pressure

The pollution haven pressure refers to the policy aspect of comparative advantage (De Melo & Mathys, 2010). If consumption in developed countries does not change proportionately in response to the structural change in production, then a situation of displacement of dirty productions may occur. In other words, if developed countries would want to maintain their pattern of consumption; then dirty industries may tend to migrate from the developed countries whose environmental regulations have grown tighter as predicted by pollution haven pressure to weaker regulatory countries which are mostly developing and emerging economies (Copeland & Taylor, 1995). This supposes that poorer countries may tend to be net exporters of pollution intensive goods while the richer countries become net importer. Hence, the EKC observed in the developed countries is not a consented effort to reduce emission for a global cleaner environment but rather as result of specialization based on some sort of "dirty" comparative advantage. In essence, pollution on the global scale may not necessarily fall since poor countries specialize in the production of dirty and resource-intensive goods while the higher income countries concentrate on "cleaner" productions (Stern et al., 1996). This shifting of environmental effect of emission from one country to the other (either by physically relocating the firm or outsourcing parts of its production lines) is referring to as the Pollution Haven Hypothesis (Dinda, 2004).

However, substantial amount of empirical studies that have investigated the pollution haven hypothesis failed to find evidence to support the claim (Cole & Elliot, 2003b; Grossman & Krueger, 1993), since firms in highly regulated countries do not relocate systematically due to the pollution haven pressure as hypothesized. This could be attributed to the fact that pollution intensive firms are subjected to pressures

from both pollution haven and factor endowment effect (Antweiler et al., 2001). Particularly because 'dirty' industries are more capital intensive - characteristically physical capital intensive (Cole & Elliott, 2002) and relatively human capital intensive (Cole, Elliot, & Shimamoto, 2003)- and may be more competitive where there is capital abundance, hence the two pressures may cancel each other out (Antweiler et al., 2001; Cole & Elliott, 2003b; Cole & Elliott, 2005).

Ederington, et al. (2005), attributed the lack of compelling evidence to support the pollution haven hypothesis to three reasons. First is that, the chunk of international trade often occur amongst developed countries whose regulations are similarly stringent, as such aggregate trade pattern analysis is unlikely to reveal the trade-environmental regulation nexus that occur between developed and less developed economies. Secondly, the cost of environment is minimal or forms a small portion of the total cost of production of polluting firms. Hence, the pressure for the firms to relocate is virtually negligible but there may be some small section of industries whom may find it costly and may fall into the pressure of pollution haven. Their final argument was that, industries have different degrees of flexibility, some are more 'footloose' than others. As such, those that have huge fixed plant costs, high transport costs of mobility or enjoy some benefits from economies agglomeration are less likely to relocate physically. Thus, previous studies that mixed analysis of relatively footloose and immobile industries may fail to detect the pollution haven.

Ederington et al.(2003) provided proof of all three argument in the US using industry-level data from 1978 to1992. In their study, air quality in the US was found be greatly influenced by changing technology rather than the shifting of dirty industrial activities abroad (Levinson, 2009). Theoretically studing aspects of immobile industries and the level of economies agglomeration, Zeng and Zhao

(2009), desmostrated how agglomeration can cancel out pollution haven expecially if there exist just a minor difference in stringency of regulations between the developed and developing countries. Wagner and Timmins (2009) illustrated that pollution haven pressure can be detected only if the agglomeration effects are controlled for.

It is therefore, probable that previous studies failed to detect the pollution haven pressure because such studies were not targeting industries that are more relevant or have trade flows with economies that are relevant to the argument. This claim was supported by Ederington et al. (2005), when they provided proof for trade patterns in the US industries. What is unclear is whether these findings pertain to US alone or it could be piloted in all major industrial countries.

It is, however, worth noting that US specialization in pollution intensive sectors does not prove to be lower, or falling any rapidly, than the cleaner sectors (Cole et al., 2003). This, Cole et al. (2003) attributed to the composition of determinants of US specialisation, which requires more physical and highly skilled human capital. Moreover, industrial processes that use highly skilled labour tend to be pollution intensive processes (Cole et al., 2003).

The correlation between physical capital intensivity seems to be well grounded. What is yet to be recognised by trade-environmental literature is the human capital requirement of the pollution intensive sectors. The general assumption of Cole et al. (2003) is industries that uses highly skilled labour tend to be pollution intensive and that cleaner sectors tend to use relatively low skilled labour. If this claim is true, then Africa's environment should be adjugde one of the cleaners since its production process rely heavily on low-skilled employees. This however, does not seem to be the case. Partly because of the loose environmental regulations across Africa countries which resent a comparative advantage in pollution intensive sector of the region

(IPCC, 2001). This follows that whether a country will be subjected to the pollution haven pressure or not depends on the environmental regulations.

2.2.2.3 Environmental Regulation

The environmental regulationscould either be formal or informal (Dinda, 2004). Formal regulation could take the form of treaties signed by countries to enforce environmental regulations which are passed on to state institutions and other regulatory bodies to carry out. But when formal regulations failed or turn to be laxer, societies take up the mantle of reducing environmental pollution through the use of informal channels and other market forces. Evidence have shown that environmental policies in developing countries are strengthned when countries shift from centrally planned economy to market-oriented regimes (Dasgupta et al., 2002; Vukina et al., 1999). Unless environmental regulations are stringent, pollution would increase (Hettige, et al., 2000).

It is believed that stringent environmental regulations reduce country's competitiveness in the world trade, if environmental externalities resulting from trade are to be paid for. If this claim is true, then the structural change in production signified by the composition effect may result in pollution 'leakage' or shift as 'dirty' firms relocate physically to economies with less stringent regulations or are displaced simply by similar dirty firms in environmental abundant countries. That is because, the assumed change in structure of production explained by the composition effect finds it root in the consumption pattern and free trade (Stern, Common, & Barbier, 1996; Ekins, 1997; Rothman, 1998). Thus, if consumption patterns remains unchanged, there may be the need to produce them elsewhere. It is therefore

important that environmental institutions and policies advance in response to economic growth.

In an open economic model with two-commodities, Siebert (1977) (as cited in Xing & Kolstad, 1996) conducted a comparative static analysis for the relative prices of commodities. The model use one nontradable resources as input and pollution modeled as a by-product of production. The relative prices of commodities were modeled as a function of environmental pollutants. Siebert's model reveal that marginal product of an industry is not the only determinant of relative commodity prices, rather damages sustain socially, pollution tendency of industries and unit effluent charges should be added. As such industries should be made to absorb the social damage through the payment of effluent charges. Siebert suggested thatenvironmental regulations be enforced by the agency in charge of environmental protection.

Similar conclusions were arrived at by Baumol and Oates (1989) (as cited in Xing & Kolstad, 1996). Their model present two countries producing identical traded goods. Both countries produce some pollution in the cause of production. Baumol and Oates conducted a partial equilibrium analysis and argued the need for environmental protection programmes. They suggested that, if countries do not make effort to enforce environemental regulations, comparative advantage of the country will be bias toward pollution-intensive industries. The country in turn specialises in pollution-intensive industry at the expense of environmental pollution.

In some cases, technology standard are more preffered to effluent fees by the environmental regulations. In an open economy with domestic firms producing only one commodity for the international market,Carraro and Siniscalco (1992) examine the effect of those environmental regulations that require new technology standards.

Their model assumed capital goods and technology are not traded. It also assumes that all countries have identical technology and that home country upon engaging in free trade imposes mandatory technology staandards to curb pollutions. This investment in new technology rises the marginal cost of the goods produced and subsquently reduce profit margin. Using perfect competition, Cournot oligopoly and Bertrand oligopoly conditions, Carraro and Siniscalco (1992), analyse how profits are affected by this emission control policy. They argue that, the new technology requirement by environemtal regulations coupled with the competition faced by domestic industry in world trade will thwart competitiveness of domestic industry, leading to profit losses. They suggested that government subsidies for the lost of competitiveness to keep domestic industry in business or risk them relocating to other countries.

It is clear from these theoretical arguments that there are efficiency losses and externalities from trade and governement has a role to play to sustain industry's competitiveness and reduce pollution. In many developing countries governements' inability to compensate for distortions in competitiveness cause most goovernment to become incensitive towardstrengthening Environemtal Protection Agencies or enforce environmental regulations. This exposes the fear for a pollution haven in developing countries.

2.3 Empirical Reviews

From the above discussion, it is clear that the income-pollution effect is a multifaceted phenomenon and is influence by a host of other factors. However, it is worth noting that most of these factors are monotonically increasing with income. Nonetheless, this study focuses on examining the pollution dynamics specific to

international trade. Therefore, this section reviews some empirical works done specifically on the EKC and the trade induced pollution.

2.3.1 Income-Pollution Effect (EKC)

There are some evidences of the inverted U-shaped income-environmental pollution relationship. An examination of the income-environment relationship by Horii and Ikefuji (2014) reveal a short run trade-off between economic growth and the environment. He, however, suggested that both variables can be improved in the long run given appropriate policy implementations. Stokey (1998), adopting a structural model, proved the inverted U-shaped relationship between income growth and pollution. Using a statistical formulation, Chow and Li (2014), provided a strong evidence for CO_2 emissions which validate the EKC hypothesis. In an attempt to investigate the link between human development, economic growth and the environment, Constantini and Monni (2008), found evidence for the existence of the EKC hypothesis. Testing for the existence of EKC in 30 countries and controlling for country location, Thompson (2014) found evidence for water pollution. He used water pollution as proxy for environment damage. His study showed the existence of EKC for both countries bordered by river and those without water bordering them. Zafar, et al. (2013), used time series data between 1980-2011 for Pakistan to investigate the impact of trade liberalisation and corruption on the degradation of the environment. Their study found evidence for the EKC hypothesis by using air and water pollution as proxies for the level of enviromental degradation. Villanueva (2011) also by including institutional variables to the EKC model, validated the EKC hypothesis.

However, some empirical studies have failed to find significant proof to support the EKC hypothesis. Using world wide cities' data for SO_2, smoke and total

suspended particles, Harbaugh, Levinson, & Wilson (2002)were unable to find sufficient evidence to validate the EKC. According to Perman and Stern (2003), EKC would fail to exist when data used for the estimations have suitable statistical properties and if the appropriate techniques of econometrics are used. Indicators used as proxy for environmental pollutions (see, Grossman & Krueger, 1995; Harbaugh, et al., 2002) could significantly influence the validity of the EKC. Moreover, the econometric models of estimation adopted could also influence whether or not EKC exist (see. Binder & Neumayer, 2005). Dasgupta, et al. (2002) argued the non-validity of the EKC by providing evidence of reductions in pollution levels of developing economies. They proved that if developing economies take steps to abate pollution, there is hardly any incidence of emergence of the EKC. On the contrary, Cole and Neumayer (2005) found that even under high economic growth, enviromental quality will rather worsen in developing economies.

Coondoo and Dinda (2002) in an attempt to investigate the EKC hypothesis in different countries and regions, conducted a Granger causality test for CO_2 emissions and income across these economic units and found no support for the EKC. Using time series data from 1960 to 1990 for 74 countries, Stern and Common (2001) also examine the EKC for sulphur emission. They failed to provide any evidence for the existance of EKC in these economies. Schubert and Dietz (2001) expanded the scope of emissions to biodiversity, to find out if biodiversity is subjected to any form of EKC effects. They did not find proof of the EKC. Stern (2004), still failed to validate the EKC. Dinda (2004) also used CO_2 as proxy for evironmental pollution to investigate the EKC hypothesis. She found no evidence of the existance of EKC, and concluded that income growth do not have significant impact on environmental degradation or pollution.

Other researchers attribute the environmental pollution to household consumption that result from the rising economic growth (see, Lin , et al., 2016). Lin et al (2016) came up with that conclusion when they set out to analyse the EKC specific to Africa. They found that economic development does not significantly cause CO_2 emissions, rather, energy structure and energy intensity were found to be the main drivers of CO_2 emissions in Africa.

These findings to a larger extent downplay the EKC hypothesis as there is the likelyhood of more than one turning point of the EKC. An example is the works of Binder and Neumayer (2005) who failed to find evidence for a quadratic EKC. Instead they found evidence of a curve with more than one turning point. Binder and Neumayer (2005) found the so called S-shaped relationship between income and pollution when they adopt an OLS estimation. They, however, reported no second turning point when they applied the random-effect estimator. Their random-effect modelling validate the traditional EKC. These results generally corroborated the supposition of Perman and Stern (2003). That is to say, econometric modelling may have some inherent bias which considerablly affect the kind of outcome an individual researcher comes out with.

2.3.2 The Trade-Pollution Effect

Amidst the controversies surrounding the traditional EKC curve, it's by far, the most comprehensive theoretical framework for examining the trade-environment relationship. Using World Banks data on China for the period 1987-1995, Dean (1999) confirmed the existence of trade-environmental Kuznets's curve. Thus, trade openness was found to be beneficial to the environment. She, however, argued that emission per unit of value added was likely to go up for many of China's provinces

1992 to 1995 if China had not implemented the exchange rate reform in 1991. Thus, the detrimental effect of free trade is outweighed by the benefits.

Similarly, in a case study of Indonesia using time series extended data for the periods 1992-2010 and 2010-2020, Strutt & Anderson (2000) proved that trade policy reform would improve and reduce natural resource depletion. Particularly because Indonesia is an industrialized country highly endowed with natural resources, hence gains from trade are estimated to be high should they adopt more outward orientated trade policies.

These findings are consistent with the conclusions of Antweiler, et al., (2001) on SO_2 emission. Antweiler et al. (2001) tested the trade-environment hypothesis using a pooled cross-country time series data for 43 countries over the period of 1971-1996. They found that SO_2 emission rises with increasing GDP (depicting a positive scale effect), decline with increasing GDP per capita (depicting negative technique effect) and decline with freer trade (showing negative composition effect). They concluded that environmental quality improved with increase trade openness. Their study reveal that trade-induced SO_2 emission originated from both ERE and KLE; and that the two opposing force seemly cancels each other out.

Likewise, Cole and Elliot (2003a), using time series data for the period 1975-1990, estimated the three effects for country level emission per capita for SO_2, CO_2, NO_2 and biochemical oxygen demand (BOD) using the General Least Square (GLS) estimation approach. They added scale effect to technique effect and called it scale-technique effect. Their result on SO_2, to a larger extent, supports that of Antweiler et al. (2001) but they were quick to add that CO_2 and nitrogen oxide is likely to increase with increase trade openness. But their results were unclear as to whether the trade-induced CO_2 emission originated from the environmental regulation or/and factor

endowment effect. They found weak evidence and are unable to validate the supposition that the ERE and KLE cancels out.

In an attempt to critic Cole and Elliot (2003a), Managi, et al. (2008) employed the Dynamic Generalized Method of Moment (GMM) estimator to test whether trade liberalisation reduces pollution in the OECD and non-OECD countries. Managi, et al. (2008), found that greater openness to trade negatively affect emission of all the pollutants (BOD, SO_2,CO_2) in OECD countries. In non-OECD countries, only BOD was found to be declining with increasing trade openness. Basically, SO_2 and CO_2 recorded positive signs for both scale-technique effect and composition effect. Also, emissions declined with increasing levels of income in OECD countries and increased with increasing incomes in Non-OECD countries.This, they attributed to the disparity in income and technology advancement in the two groups. They concluded that the trade-induced emission stem from both ERE and KLE in both OECD and Non-OECD countries but the two effects did not cancel each other out since ERE appear to have dominated KLE for all pollutants. In another attempt to validate the trade-environment effect, using cross-country data, Frankel and Rose (2005) estimate the relationship at a given GDP level. They reported that trade openness have increased SO_2 and NO_2 and particulate matter emissions.

In essence, free trade that is meant to increase industrialization and volumes of export and also foster expansion of economies and promote income growth (Vutha & Jalilian, 2008), may turn to be detrimental to the environment if not managed well. Using panel data for 63 developed and developing economies from 1960 to 1999, Managi (2004) found trade openness to be harmful to the environment. This finding was contended by Beckerman (1992), who posits that higher levels of income from trade may rather reduce degradation of the environment, thus income or economic

growth could be preconditions for improving the environment (Bhagawati, 1993). Halicioglu (2009) found the opposite. He provided evidence that income growth is the main determinant of CO_2 emission in Turkish economy.

Dinda (2004) corroborate the supposition of Antweiler et al. (2001) , when she failed to find evidence for the EKC for CO_2 using the reduce income model of EKC. She argue that free trade is one of the most essential factors that can explain the Kuznets hypothesis. If there must be any EKC relationship, then its largely due to the role of international trade in distributing 'dirty' industries (Arrow, et al., 1995; Stern, Common, & Barbier, 1996). Moreover, trade openness affects the national output composition either by promoting some sectors of the economy or/and prohibiting others, thereby changing the incidence, type and level of environmental pollution across nations and regions (Vilas-Ghiso & Liverman, 2006)

The above finding raises the question of the role of countries' output composition on emissions. Vossenaar (2013) describe liberalising trade in environmental goods as "triple win" situation for trade, environmental quality and development. Broadly speaking, environmental goods and services industry can be defined as "activities which produce goods and services to measure, prevent, limit, minimise, or correct environmetal damage to water, air and soil, as well as problems related to waste, noise and ecosystems" (OECD, 2005; p. 42). Countries turn to import these environmental goods when income increases, which in turn calls for structural changes. This in turn move country's competiveness from resource-base outputs to dynamic technological outputs.

Therefore, the extent to which a country's openness to trade influences pollution emissions is determined by its comparative advantage (Antweiler et al., 2001). The comparative advantage in pollution intensive goods is grounded on the

relatively low level of a country's income (Copeland & Taylor, 1994), which allows for laxer regulation of the environment. Therefore, quality environment is deemed a normal good whose demand increases with income. Thus, as free trade increases income, the resulting scale effect is nullified by the technique (Copeland & Taylor, 1994) through investment in Research and Development (R& D) (Komen, et al., 1997) which allows for more inovative ways of production. In essence, the net impact of trade on the environment is determine by the composition effect. The composition effect is primarily determined by the country's comparative advantage (Cole & Elliott, 2003a) which could be in the form capital-labour ratio and/ or environmental regualtions (Antweiler et al., 2001). Relatively, the strength and direction of the composition effect will determine the difference in environmental impact of trade openness across countries.

That goes to reaffirm the fears for the possibility of the emergence of the displacement and polution haven hypothesis in African countries, who are predominantly developing countries. Such developing countries, according to Copeland and Tayor (1995), tend to have weaker environmental regulations. Thus composition effect is likely to be positive as found by Dean (1999) and Cole and Elliot (2003a).

An extension of the findings of Antweiler et al. (2001) shows that trade openness caused a shift in the output composition of poorer countries toward pollution intensive goods. It is only after adding the three effects together were the authors able to conclude that "trade is good for the environment". However, the authors were quick to add that such a reduced single equation model may not fully explain the extent to which trade policy affects emission. Moreover, the overall impact of trade openness on SO_2 emission in Cole and Elliot's (2003a) result would be difficult to

ascertain; considering that the scale-technique effect is negative and composition effect positive. It will be difficult to estimate which effect outweighs the other and at what level of income does the transition begins. The most valuable information that a positive composition can provide is that environmental regulation or institutions are weak. Thus, as trade openness increase emission increase unabatedly.

2.3.3 Environmental Regulations, Trade and Pollution

The debate about the effect of environmental regulations on comparative advantage of countries has generated much empirical works. Proponents believed that environmental regulations are instrumental in ensuring environmental quality, as they can aid in the transition process from the threshold point toward the improvement phase of the EKC. There is also the issue of environmental regulations serving as secondary barriers to trade for protection of domestic environment. In this case, there is some level of endogeneity between stringency of environment regulations and trade. When treated as endogenous, environmental regulation was found to influence trade patterns in the US (Ederington & Minier, 2003; Levinson & Taylor, 2008).

In examining the effects of environmental regulations on trade, Ugelow (1982) (as cited in Xing & Kolstad, 1996) review ten empirical works of the 1970s. He found no conclusive evidences to support the relationship.Conducting a micro-level analysis of the performance of four industries on environmental programme in the United State, the U.S. Commerce Department (1975) reported that trade patterns and the comparative advantage were slightly influenced by the environment programme. However, this effect was reported only for the short run. In contrast, Walter (1982) and Robinson (1988) signified that such effect could be significant. Though difficult to estimate the true impact of environmental regulations, these empirical evidences

suggest that the effect of environmental regulations on trade may be less important than implied in theory.

Pasurka (1985) also examine the impact of environmental regulations on international trade in the U.S. His study looked at the changes in "effective protection rate" resulting from cost of environmental control. The U.S. tariff structure makes available the effective protection rate as form of protection to the industries. Pasurka (1985) provided evidence of how direct environmental costs influenced the effective protection. His findings reveal that the effective protection rate decrease by 20 percent due to cost associated with environmental control programme. Walter (1982) found a 27 percent loss to effective protection rate when he used the 1971 data.

In two attempts to analyse the effect of environmental regulation on international trade, Robinson (1988) found some substantial effects. The first attempt made use of time series data on ratio of imported and exported abatement cost associated with each dollar of a product's value. He used this to examine the changes in patterns of trade and comparative advantage. The findings reveal that, between 1973 and 1982, there was an increase in the ratio from 1.17 percent to 1.39 percent. This implies the value of U.S. imported goods contain more environmental control cost than exports leaving the United State. Robinson attributed the results to a shift in patterns of trade toward exporting environmentally "clean" goods and importing dirty goods. In other words, the US calm down on producing pollution-intensive good by shifting its comparative advantage to less pollution-intensive industries. With consumption remaining the same, trade patterns shifted towards importation of pollution-intensive goods.

Secondly, using a partial equilibrium approach for individual polluting industries, Robinson examines the marginal effect of abatement costs on trade

balance. He constructed a trade balance equation comprising 78manufacturing and agricultural sectors, instead of using the aggregate trade balance. He assumes that the value of the final product includes all environmental costs. He added that the price elasticity of quantities exported and imported quantities and their relative prices to determine the relationship between abatement costs and international trade. Robinson found for all sectors under consideration, in exception of mining, a negative relationship between stricter environmental regulations and exports. He found that trade balance of agricultural products falls by 245 million dollars when abatement costs induced a 1 percent rise in price. In decomposing the $245 million reduction in trade, Robinson found that $95.8 million is due to reduction in exports of agricultural goods and increased importation of agricultural goods. The reminder, he attributed to the spillover effect of the agricultural prices on other sectors. This result implies that environmental regulation could significantly influence trade if environmental costs are fully internalized in the pricing mechanism. It is however, unclear how abatement cost could drive a wedge between prices.

But these environmental regulations or user cost of environment may be counter productive if it varies across regions of a country. For example, the Carbon motivated border tax adjustments (CBTA), which act as a user cost of environment, may affect producers' competitiveness (Boqiang & Aijun, 2011), but only to the extent of the degree of 'footloose' nature of their firms. When CBTA differ across regions, firms may move production to the gray areas to avoid the environmental tax.

In a simulation for economic and environmental effects, Peterson & Joachim (2007) argue that CBTA is not entirely effective in decreasing carbon leakage. This assession was corroborated by Boqiang and Aijun (2011) who conducted a simulation in Chinese provinces, and argue the CBTA is not "an effective instrument of combat

of carbon leakage" (p. 5117). This is partly because different regions are exposed to different levels of trade openness, as such CBTA (just like any other environmental regulations) affects the different regions and sectors differently (Boqiang & Aijun, 2011). The regions that are highly opened to international trade are more likely to be subjected to adverse effect of CBTA. As such, the CBTA could result in shifting of production lines from industrial products to non-industrial product, and the relocating of production across provinces which will promote carbon leakage or emission growth. In such an instant, emission growth from international trade originate to due the loophole in environment tax.

Other studies that have investigated the level of sensitivity of international trade to environmental policy in the bid to describing the trade-environment effects have also expose some controversial findings. These studies hypothesis that because exporting sectors are mostly resource-based, they turn to be pollution intensive. As such, stringent environmental regulations may stiffen competitiveness of these sectors. In essence, stringent environmental policy negatively impact export. However, import is expected to increase as consumers substitute more expensive domestic goods for the cheap foreign ones. Notable among this line of research is that of Tobey (1990) and van Beer and van den Bergh (1997). In a multi-country research, Tobey (1990) did an impact analysis of domestic environmental regulations and free trade. Following from the Heckscher-Ohlin-Vanek model of international trade, he found that environmental policy do not significantly influence trade.

On the other hand, van Beers and van den Bergh (1997) found a significant effect of stringent environmental policy on both export and import flows. They used the gravity model of bilateral trade flow. Van Beer and van den Bergh (2010), found a contradictory result in their subsiquent study which used Tobey's (1990) measure of

environmental policy, sampled different countries and varied the sectors of focus. The impact of environmental policy on export was found to be insignificant. This finding is consistent with that of Tobey (1990).

Van Beer and van den Bergh (2010) however, attributed the lack of evidence to support the hypothesis to three reasons. Firstly, they suspected that introduction of subsidies to pollution intensive sectors of countries that practice stringent environmental regulations may result in the cancellation of the stiffening effect of environmental policies. Thus, environmental tax and subsidies contradict each other. In other words, the subsidies make up for the increased cost of production brought about by the imposition of environmental tax. If the subsidies or tax holidays exceed environmental tax, polluting firms will have no incentive to reduce pollution or invest in cleaner technologies. Secondly, insufficient data due to the 'footloose' nature of some firms was projected to have accounted for the lack of evidence. Aside from environmental cost, other variables like skill sets of required labour and political instability or instability can influence relocation of firms, particularly the footloose ones, or decisions of firms to continue exporting or not. When these disturbances are present in sample population, regressions may not reflect the true effects. Finally, the measure for stricter environmental regulation adopted by Tobey (1990) was questioned; it was more of an input-oriented indicator. They suggested that an output-oriented indicator would have been more suitable.

The theoretical review and empirical studies appear to be inconsistent. All the theoretical arguments suggested some form of distortion in a country's comparative advantage and trade pattern due to the presence of environmental regulations. But some empirical studies, such as those by the U.S Department of Commerce (1975) and Toby (1990) proved otherwise. They failed to support the significant relationship

between trade and environmental regulations as put forward in theory. Some of the empirical studies that supported the theory found very minimal effects; less than expected.

It is clear, however, that the relationship between trade and the environment is complex and for a number of reasons pose more questions about the models use in empirical literature above. Firstly, most of the estimations are implicitly grounded on the basic Kuznets curve framework which depends on the *income elasticity of demand for a cleaner environment* to be in the excess of unitary. Such that most of the EKC models estimation done emphasized the inclusion of income elasticity of demand for cleaner environment (Beckerman, 1992; McConnell, 1997) since it is the main explanation given to the declining phase of the Kuznets curve. It is expected that after a particular level of income, peoples' willingness to pay for cleaner environment should be greater than unitary (Roca, 2003)but it is obvious that the main determinants of environmental damage are monotonically increasing in income. As such, the elasticity of environmental quality may be less than one since the elasticity function is not that of income alone (Managi et al., 2008). If this is true, then emission growth from trade may not be responsive to environmental tax or environmental policy may practically become "impotent". Corrupt governance practices may also cause government to be irresponsive to demand for cleaner environment by citizenry thereby hindering the technique effect (Welsch, 2004).

Secondly, most of the studies above that tested the pollution hypothesis adopted pooled cross-sectional data which turn to assume away heterogeneity effects. These estimations are biased since they assume that the economic development trajectories of all the countries under observation are somewhat the same. Thirdly,

Managi, et al (2008) argue that previous studies have failed to take into consideration the endogeneity effect of trade openness and income.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter presents the methodology used in the study. The chapter is further divided into five sections. Aside this introductory section, second section focuses on the empirical model that informed this study. Section three covers the modifications made to the model of estimation. The fourth section covers issues relating to the data and the definition of variables. Section five focuses on the strategy of estimation.

3.2 Empirical Model Specification

The study is motivated by the work of Cole & Elliot (2003a). Since their specification is pivotal to this study, it is convenient to provide a brief overview of their model. Cole and Elliot (2003a) building on the works of Antweiler et al., (2001) point out that people's demand for pollution is not just a positive function of scale effect but depends on the level of trade restriction, whose direction depend on whether a country imports or exports pollution intensive goods. Their model allow for comparative advantage to be capture by what Antweiler el at., (2001) call factor endowment and/or pollution haven motive. From this theoretical consideration, they estimate fixed and random effects using the following model:

$$E_{kt} = \alpha_o + \alpha_1 KL_{kt} + \alpha_2 (KL)^2 + \alpha_3 I_{kt} + \alpha_4 (I_{kt})^2 + \alpha_5 KLI_{kt} + \alpha_6 O_{kt} + \alpha_7 O_{kt}\, RKL_{kt}$$
$$+ \alpha_8 O_{kt}(RKL_{kt})^2 + \alpha_9 O_{kt}\, RI + \alpha_{10} O_{kt}(RI_{kt})^2 + \alpha_{11} O_{kt}\, RKL_{kt}\, RI_{kt}$$
$$+ \alpha_{12} T + \varepsilon_{kt}. \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where E_{kt} represents per capita emissions in country k at year t, KL_{kt} shows the capital-labor ratio, and I_{kt} is the lagged value per capita income for one period. KLI_{kt} is the cross product of KL and I which is meant to explain the likelihood that pollution

impact of income depends on the existing capital-labour levels. O_{kt} denotes trade openness (the ratio of sum imports and exports to GDP). The interaction between trade openness with country's relative capital-labour is capture by $O_{kt}RKL_{kt}$. O_{kt} RI_{kt} captures the interaction of country's trade openness with its relative income. They further captured an interaction of trade openness, relative capital-labor ratio and income relative to each country with $O_{kt}RKL_{kt}$ RI_{kt}. The T was included to capture a linear time trend.

In Cole & Elliot's (2003a) model the country's capital-labour ratio was used to capture the composition effect. The quadratic of capital-labour ratio was included to account for diminishing effect of capital accumulation, the interaction between capital-labour ratio and lagged per capita income captures the income effect on pollution which is likely to be a function of the existing capital-labour level, and vice versa. Cole and Elliot measured scale and technique effect together (in what is termed as the net scale-technique effect) using lagged GDP per capita. Their study used the large scale effect at low income level and large technique effect at high income levels to explain the income-pollution U-shaped relationship.

3.3 The Model

The empirical model of this study follows that of Cole & Elliot (2003a) with some modifications. Modifications that were made to Cole and Elliott's model involved the (1) inclusion of the lagged dependent variables (CO_2) as an explanatory variable, (2) removal of the interaction term between capital-labour ratio and income (KLI_{it}) due to multicolinearity, (3) the introduction of interaction between foreign direct investment inflow (FDI), relative capital-labour ratio and relative per capita

income, (4) environmental regulation. Reasons for the inclusion and exclusion of these variables has been provided in section 3.4.

The linear form econometric model is presented in equation 2 below:

$$\begin{aligned} \ln E_{it} = {} & \beta_0 + \beta_1 \ln E_{it-1} + \beta_2 \mathrm{In}(\mathrm{lG}_{it}) + \beta_3 \mathrm{In}(G_{it})^2 + \beta_4 \mathrm{In}(O_{it}) + \beta_5 \mathrm{In}\left(\frac{K}{L_{it}}\right) \\ & + \beta_6 \mathrm{In}\left(\frac{K}{L_{it}}\right)^2 + \beta_7 \mathrm{In}(O_{it})(RG_{it}) + \beta_8 \mathrm{In}(O_{it})(RG_{it})^2 \\ & + \beta_9 \ln(O_{it})\left(R\frac{K}{L_{it}}\right) + \beta_{10} \ln(O_{it})\left(R\frac{K}{L_{it}}\right)^2 \\ & + \beta_{11} \ln(FDI_{it})\left(R\frac{K}{L_{it}}\right)(RG_{it}) + \beta_{12} ER_{it} + \varepsilon_{it} \ldots\ldots\ldots\ldots\ldots\ldots\ldots (2) \end{aligned}$$

(t = 1990, 1991... 2014; i = 1, 2, ..., 18)

where E_{it} represent emissions (CO_2, N_2O, CH_4, and total F-gases) of country i in year t measured in thousand metric tons. β_0 to β_{13} are the coefficients, and $\varepsilon_{,it}$ is the disturbance term. E_{it-1} is the lag of each of the emissions measured in thousands metric tons and K/L_{it} shows the capital-labour ratio. G_{it} denotes lagged income per capita. O_{it} is the term measuring trade openness. RK/L_{it} is the relative capital-labour ratio and RG_{it} is the country's relative per capita GDP. FDI represent foreign direct investment inflow whereas ER_{it} represent a country's environmental policy and institution effectiveness indicator.

Theoretically, increasing trade openness would increase levels of pollution for economies with higher capital-labour ratio and decrease emission for lower capital-labour ratio countries.On the other hand, increasing trade openness would increase pollution in low income countries and decrease pollution in the high income countries (Cole & Elliott, 2003a). These two opposing effects are what Antweiler el at., (2001) respectively called the factor endowment and pollution haven (environmental regulation) motive of pollution. Extracting these two components from equation (2) gives the theoretical basis forthe overall trade-induced composition effectof country i

(C_i,)which according to Cole and Elliott (2003a) can be expressedformally as equation (3).

$$C_i = \delta_0 \ln(O_i) + \delta_1 \ln(O_i)(RG_i) + \delta_2 \ln(O_i)(RG_i)^2 + \delta_3 \ln(O_i)\left(R\frac{K}{L_i}\right) + \delta_4 \ln(O_i)\left(R\frac{K}{L_i}\right)^2 + \delta_5 \ln(FDI_i)\left(R\frac{K}{L_i}\right)(RG_i) + \delta_6 ER_i \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (3)$$

From equation (3), we expect $\delta_1 > 0$ and $\delta_2 < 0$ for the environmental regulation effect to hold. The factor endowment effect, on the other hand, predict that $\delta_3 < 0$ and $\delta_4 > 0$. According to Antweiler et al (2001) as cited in Cole and Elliott (2003a), trade openness as a standalone parameter should not influence emissions. It is believed that the environmental effect of opening trade is country specific and solely determined by the country's comparative advantage, therefore $\delta_0 = 0$. The signs on δ_5 and δ_6 could be negative or positive.

3.4 The Data and Variable Definition

This section presents discussions of variables grouped under explainatory and dependent variables. The data for the study is sourced from World Banks' World Development Indicators (WDI) and it covers 18 independent Africa countries spanning from 1990 to 2014.

3.4.1 Explainatory Variables

The discussions concerning the explanatory variables herein are done as they appear in equation(2). In all, there are twelve terms explaining the trade-emission nexus which are discussed below.

3.4.1.1 Lagged Dependent Variable (E_{it-1})

The first modification made to the model is the inclusion of the lagged dependent variables (carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4) and flourinated gases (Fgases)) as an explanatory variable. The decision to include the lagged dependent variable is purely a theoretical one as it is believed that current levels of emission is highly influenced by the past emission levels. For example, it takes methane emitted today about a decade to leave the atmosphere, and nitrogen oxide about a century but CO_2 after emission, could partly evacuate the atmosphere in a century while about 20 percent is left behind to last for about 800 years from time of emisson (Forster, et al., 2007). Hence, the non-inclusion of the lagged dependent variable may result in omitted variable bias rendering results unreliable. According to Arellano and Bond (1991), including the lagged dependent variable allows for the dynamic effect to be captured.

3.4.1.2 GDP per Capita

Following from Cole and Elliot (2003a), the lagged per capita income is meant to absolve the net scale-technique effect. If production mix and techniques of production are immutable, then large scale of global economic activity brought about by extraction can in itself change technologies of production in a manner that will reduce emission (Grossman & Krueger, 1995). If this supposition is true, then both scale and technique effects are determine by income, yet they run in opposite direction. The scale effect is expected to be positive whereas the technique effect is negative. Putting the two effects together (scale-technique effect), we expect a negative sign if trade openness is to be compatible with environmental sustainability. In other words, the negative technique effect should outweigh the positive scale

effect. However, if the lagged income (scale-technique effect) is positive, then scale effect outweighs the negative technique effect. The positive sign is not desirable since it is damaging to environmental quality.

Relative GDP per Capita

Unlike Cole and Elliott's model where the relative income and capital-labour ratio is calculated relative to world average, this study express them relative to Africa's average. It is important to also note that relative GDP per capita is calculated using a simple average approach. This calculation are done taking into consideration the 50 independent Africa countries. The GDP per capita of each country in Africa, at a specific time, are added and divided by the number of countries to ascertain a time specific per capita income for Africa.

$$Africa's\ per\ Capita\ GDP\ (G_{At}) = \frac{\sum_i^n G_{it}}{N}$$

The resulting quotient becomes the denominator of a fraction whose numerator is the country specific GDP per capita at time t. The result of this division gives the relative GDP per capita for each country at time t.

$$Relative\ per\ Capita\ GDP\ (RG_{it}) = \frac{G_{it}}{G_{At}}$$

It is believed that indexing the per capita GDP of countries in the region to world per capita income as a way of calculating the relative per capita GDP will amplify the income disparity gap between developed and developing countries. Thus, the need to calculate relative per capita GDP specific to the region.

3.4.1.3 Trade Openness

The term *trade openness* is used interchangeably with *trade liberalization* in literature. Though closely related, the two concepts are not identical. Trade openness

basically refers to an increase in the size of the traded sectors of a country relative to its total output. Trade liberalization on the other hand, encompasses policy measures aimed at increasing trade openness. In essence, increased trade openness can result from, but not limited to, trade liberalization. Simply put, trade openness is the trade intensity of an economy(Pritchett, 1996). Recent studies have defined trade openness as identical to the idea of free trade, a trading system where all distortions are removed. These studies have describe trade openness in relation to removal of barriers to international trade which include tariffs and non-tariffs barriers, transport cost, and taxes (see, Feenstra, 2004; Harrigan, 1993). These definitional differences makes it unclear which standard of trade openness in superior.

For the purpose of this study, trade openness is defined as percentage of the sum of exports and imports to GDP, which is generally used in the growth literature as a proxy for international trade openness (see, Antweiler et al., 2001; Frankel & Romer , 1999).According to Antweiler et al (2001), trade openness per se should not influence emissions. Rather the effect of openning the economy will affect the environmental quality through the country specific comparative advantage. If this claim is true, then we expect the coffiecient of trade opennes to be zero (that is, $\delta_0 = 0$ and $\beta_4 = 0$).

3.4.1.4 Capital-Labour ratio

The capital-labour ratio ($K/L_{it)}$ is included to capture direct country's composition effect.The capital-labour ratios remains important in describing industry patterns of trade (Kowalski, 2011). Any interferance with comparative advantage – be it a support from government to sectors where 'natural' comparative advantage exist – would decrease trade gains or probably negate it (Deardorff, 2011). Theoretically,

capital-intensive production processes are supposed to be more pollution intensive than the labour-intensive process (see, Cole and Elliot, 2002). Therefore we expect that countries with low K/L ratio should experience low pollution relative to the high K/L ratio countries. As shown in Table 1, the mean K/L ratio is as low as $336.465. As such the capital-labour effect on emission should be negative. The square of capital-labour ratio $(K/L_{it})^2$ is included to account for diminishing effects on capital accumulation. Being a regional level analysis with spatial differences between individual countries, there is the need to incorporate relative capital – labour ratio in the estimation.

Relative Capital-Labour ratio

In this study, the relative factor endowment of countries is estimated through a series of mathematical computations. The *Gross capital formation* is used as a proxy for capital (K). It is worth noting that the Gross capital formation is defined by the WDI as additions to an economy's fixed assets plus its net changes in inventory level. Fixed assets comprise of value additions to land; plant, machinery, and equipment purchased; construction of roads, railways, schools, offices, hospitals, private residential dwellings, commercial and industrial buildings and so on. Inventories include stocks of goods that firms keep in order to meet fluctuations that temporarily or unexpectedly occur in production or sales plus "work in progress." Data is contant at 2005 US dollars.The *total population* is use as a proxy for labour (L). Thus, the general capital-labour ratio is given as $\frac{\text{Kit}}{\text{Lit}}$. Unlike other studies which used world averages, this study ascertain total capital specific to Africa through a simple average calculation for each year, representated by the notation below:

$$Average\ Africa's\ Capital\ (K_{At}) = \frac{\sum_i^N K_{it}}{N}$$

Where, N represent the number of countries, Kit capture the capital of each country at time t. Hence, $\sum_i^n$ Kit, shows the summation of capital from country i to the nth country at a specific time t.

Similar analogy is used to calculate the time specific average population or labour of Africa.

$$Average\ \ Africa's\ Labour\ (L_{At}) = \frac{\sum_i^N L_{it}}{N}$$

Where, Lit explains the labour specific to each country at time t. Therefore, $\sum_i^n$ Lit, captures the summation of labour from country i to the nth country at a specific time t. Hence,

$$Average\ Africa\ Capital -\ Labour\ Ratio(ARKL_{At}) = \frac{K_{At}}{L_{At}}$$

Therefore,

$$Relative\ Capital - Labour\ Ratio\ \left(\mathrm{R}\frac{\mathrm{K}}{\mathrm{L_{it}}}\right) = \frac{Kit/Lit}{ARKL_{At}}$$

3.4.1.5 Trade Openness and Relative Capital-Labour ratio

The factor endowment effect is captured by the interaction between trade and relative capital-labour ratio ($O_{it}RK/L_{it}$) and the square term. Both together indicate one length of the indirect trade-induced composition. There is a strong positive correlation between capital intensity of a sector and the level of its pollution intensity (Cole & Elliott, 2002); Africa being a labour abundant region, we expect (O_{it})(RK/L_{it}) to yield a negative sign, whereas square term give a positive sign.

3.4.1.6 Trade Openness and Relative GDP per Capita

This term is an opposing force to the factor endowment effect captured by term $O_{it}RG_{it}$ (interaction of trade openness and relative per capita income). It is meant to capture the second length of the trade-induced composition effect known as the environmental regulation effect. It is believed that trade openness in low income countries is expected to be accompanied by increasing emission due to the laxity of environmental regulations resulting from the low economic growth. Compare to the world average GDP per capita of $10, 880(International Monetary Fund, 2015), Africa's average per capita GDP is $1635.279 (see table 1). Therefore, we expect that the interaction term between trade openness and relative per capita income will yield a positive sign, whereas its square produce a negative sign.

3.4.1.7 FDI, Relative capital-labour ratio and Relative per capita income

The second modification to Cole and Elliott's (2003a) original model is made to the interaction term between trade openness, relative capital-labour ratio and relative per capita income ($O_{kt}RKL_{kt}$ RI_{kt}) meant to capture the other portion of the composition effect. Instead of trade openness, foreign direct investment (FDI) is interacted with the other parameter (FDI_{it}. RK/L_{it} RG_{it}). This is because developing countries like those in Africa depend largely on technology transfers and capital flows in the form of FDI to improve capital accumulation (see, Dasgupta et al., 2002, Dean, 2004) which in turn influence income. Aside, influencing physical capital accumulation, FDI influence the quality of labour force as well. UNCTAD (1994) reported that Multinational Corporations enhance human capital development by providing finacial support to schools and institutions responsible for training.

In a study that examined the relationship between energy consumption, energy efficiency, income per capita, and FDI among 74 low, middle, high income from 1985-2008, Pu-Yang, et al. (2011) found that increase in FDI flow reduces the intensity of energy consumption and subsequently emission. Following from the above proposition, it is expected that FDI_{it} RK/L_{it} RG_{it} will yield a negative sign. In other words, an increase in FDI inflow should result in both physical and human capital development which will induce economic growth in a manner that reduces emission of GHGs.

3.4.1.8 Environmental Regulation and Institutions' Effectiveness (ER)

The last modification is the inclusion of *Environmental policy and institution effectiveness* indicator (ER) to explain the impact of environmental policy on emission growth. It is believe that laxity of these policies have an amplifying effect for pollution growth. Most countries are implementing various policy tools to handle GHGs. Some are applying energy taxes to fuels, others carbon taxes or both with some exemptions to protect infant industries who may be exposed to international trade competitiveness, yet still many other are looking at emission trading, energy efficiency trading and renewable energy certificate trading (OECD, 2003).

Given that countries under the UNFCCC and Kyoto protocol are using varying policy tools to meet their emssion commitment of a reduce GHGs from industry, this study adopt the environmental policy and institution index to test how effective the policy tools are at reducing emission. According to the World Bank's description of this index, it is meant to assess "the extent to which environmental policies foster the protection and sustainable use of natural resources and the management of pollution". The index is measure on the scale of 1 to 6, where 1 present weaker environmental

regulations and institutions and 6 representing tigher environmental regulations and institutions. The index is intended to explain whether the level of stringency of environmental policy and institution has an bearing on Africa's competitiveness in international trade or whether enviromental regulation constitute a comparative advantage to the region.The country's environmental policy and institution effectiveness indicator is an additional composition effect intended to capture the effectiveness of environmental regulation authorities with the view of explaining governments' responsiveness toward ensuring a clean environment. Apperently, environmental regulations in most Africa countries is adjudged less stringent (IPCC, 2001; Cole, 2003; OECD, 2011). Thus, ER term is expected to produce a positive sign.

3.4.2 Dependent Variables

Considering that all the dependent variables are pollutions, it is important to differentiate between the methods of measurment of the pollutions. This is necessary because the difference, as to whether its measured in terms of emission or concentrations, have implications for the analysis of trade-environmental pollution effect. A measurement of pollution in terms of concentration provide different information from an emission measurement. Concentration data of a particular place, be it a city, provide information that pertain more to health implications of a the pollutant on that city's pollulation. National emssion on the other hand provide a wider form of information on environmental issues and is likely to be weakly related to the concentrations at the city level (Cole & Elliott, 2003a).

As such government policy targeted at relocating dirty industries from a city or promoting city cleaner production would significantly reduce pollution at the city-

level but may not result in a national-level reduction in pollutions. Moreover, "concentrations data tend to be noisier than emissions data and require the inclusion of a number of dummy variables to capture site-specific effects" (Cole & Elliott, 2003a, pp.369). These site-specific effects can be successfully incorporated if they are fixed in nature but the time-varying ones may prove difficult to test considering that the pollutants originate from different sectors of the economy (Cole & Elliott, 2003a).

The industrial sector, in particular, is an essential source of both direct and indirect GHGs (OECD, 2003). Due to the difficulty in abating emissions in other sectors (like the transport sector) the industry's emission attract a lot of attention from policy makers as they function out ways of reducing residential GHG emissions. GHG emissions at the industry originate primarily from energy use and industrial processess (OECD, 2003). Among the six greenhouse gases recognized under the Kyoto Climate Strategy, analysis herein will group them under four categories of GHGs as discussed below.

3.4.2.1 Carbon Dioxide

CO_2 is the largest emitted GHG, which stem largely from human activities like combustion of fossil fuel and deforestation. Natural source like volcanic eruption and respiration process do emit some amount of CO_2. CO_2 continue to receive most attention from policy makers and scientist because, CO_2 has caused the most change to the climate since 1750 to 2005 and even now (Somerville, et al., 2007). Unlike other heat-trapping gases, CO_2 stays much longer in the atmosphere. CO_2 after emission, could partly evacuate the atmosphere in a century while about 20 percent is left behind to last for about 800 years from time of emisson (Forster, et al., 2007). It is worth noting that most of the industrial emission of carbon dioxide may not

necessarily feed into international trade considering that most countries in Africa are net-importers of industrial products couple with the fact that most of Africa's export are "non-industrial" in nature.

3.4.2.2 Methane

Just like CO_2, Environmental Protection Agency (EPA) stated that, CH_4 is a by product of coal – emitted during the production and transportion process of coal, natural gas and oil - as well as other source like livestock, some agriculture practices, and decay of organic waste (EPA, 2016). Unlike other heat-trapping gases, it takes methane emitted today about a decade to leave the atmosphere (Forster, et al., 2007). Though it shortly live in the environment, according to the IPCC (2001), CH_4 planet warming effects are 86 times more than that of carbon dioxide.

3.4.2.3 Nitrous Oxide (N_2O)

Nitrous oxide – which contributes about 6% to global warming (IPCC, 2001) – stem largely from synthetic fertilisers, animal dropping used in the soil as manure and agricultural waste burning. Agriculture soil constitute over 70% of total N_2O emissions as at 2010 (IEA, 2012). There exist some amount of N_2O emissions from fossil and bio-fuels combustion and industrial processes (IPCC, 2006). Infact, production of nitrogen fertiliser constitute more than half of total man-made nitrogen (Socolow, 1999). Among the regions ranked in 2010 to be producing three-quarters of global nitrous oxide, Africa find its name on that chart with 19%, Asia (36%) including China (18%) and the Latin America (14%) (IEA, 2012). What is worse is that, unlike other heat-trapping gases, it takes nitrogen oxide emitted today about a century to leave the atmosphere (Forster, et al., 2007).

3.4.2.4 Flourinated Gases

The f-gases comprising of hydrofluorcarbons (HFCs), perfluorocarbons (PFCs) and sulphur hexafluoride (SF_6) are man-made GHGs developed to replace chloroflourocarbon (CFCs) by the Montreal Protocol. They are typically used inside products such as air conditioners, refrigerators, aerosol can, foams and for the production of semiconductors and metals. Its emissions takes place during the production process - by way of gas leakage – as well as wear and tear during the product's life. The concerntration of these anthropogenic gases have increased nearly from zero 1750 to 89 parts per trillion (ppt) for HFCs and 6.7 ppt for SF_6 in 2009 (Montzka, et al., 2011). According to the 2011 United Nations Environment Programme (UNEP) report, refrigerator and air-conditioning account for 79% of HFC use. This, however, is worrying considering that most Africa countries countinue to import used frigdes and cars – with HFC serving as a coolant – which leaks out over time. The use of mobile air-conditioners in vehicles account for the largest HFCs emissions (Velders, et al., 2009), particularly the used cars and fridges. SF_6 is largely used in equipments for the transmission and distribution of electricity. Though these gases are generally emitted in smaller quantities, they are however very potent, and are somewhat referred to as High Gobal Warming Potential gases, these gases have relatively higher heat-trapping ability than CO_2(EPA, Overview of Greenhouse Gases, 2016) as such posese more destructive threat to the climate.

3.5 Estimation Strategy

A study of this nature where the data presents sets of spatial units (like regions and countries) with different locational components, there is the likelihood problems of spatial heterogeneity and spatial dependence (Arbia & Piras, 2005) and the GLS

model may not fully capture these dynamics. Moreover, in a growth model, when regional units are model with the GLS, there is an implicit assumption of absolute convergence, which may not be the case. The stylized truth is that there exists a great difference in the growth rate and per capita GDP across countries and regions as predicted by Solow (1956) conventional convergence theory. Therefore, countries conditionally converge to a steady state that is region-specific (Solow, 1956), not a general steady state as implicitly implied by Cole and Elliott's GLS model.

Another setback of Cole and Elliot's model is that it did not recognize the endogeneity that may arise between income and trade openness. In an attempt to test trade openness and income endogeneity, Frankel and Rose (2005), tackled the simultaneity problem by using instrumental variables in the traditional gravity model of bilateral trade and neoclassical endogenous growth equation. They estimated an equation each for environmental quality, trade and income with the view of testing the causality between trade and the environmental effects. Testing these three equations with a cross sectional data for 41 countries in a single year period (1990), by just observing the sign on the trade variable, they concluded that trade openness leads to a reduction in sulfur dioxide emission. It is likely that this structure of reduced equations may not fully explain the trade-environment dynamics for all year periods and across different pollutants. Hence, the need to expand the study, in terms of scope and data length, and to include other GHGs in other to prove whether their findings were time and/or pollutant specific or can apply to all other pollutants in varying time periods.

This study adopts the Generalized Method of Moment (GMM) dynamic panel estimation because it is capable of correcting for unobserved country heterogeneity, endogeneity, omitted variable bias, and measurement error (Bond, Hoeffler, &

Temple, 2001) which are normally involved in studies of this nature. The GMM estimation since its first introduction by Arelllano and Bond (1991) has received massive recognition in recent literature. Though initially used for research in areas of labour and industrial studies, many growth studies have used it, (see Managi et al., 2008; Greenaway, Morgan, & Wright, 2002;Caselli, et al., 1996 for a detail discussion on the GMM in the growth literature).

There are two forms of the GMM estimators; the difference GMM and the system GMM. The difference GMM estimator uses first differencing in eliminating unobserved individual-specific effects and correct for simultaneity using the lagged value as instrument; this does not produce satisfactory results (Blundell & Bond, 2000). The lagged values as used in the difference GMM becomes a weaker instrument since the instruments are less correlated with the regressors. The difference GMM also suffers from large sample bias and shows very low precision (Blundell & Bond, 1998). Hence, in a growth context - as in this study - where human and physical capitals are strongly auto correlated, the standard difference GMM is unlikely to perform well.

According to Blundell and Bond (2000), these biases can be attributed to the weak correlations between current levels of growth in the variables (for example, income and capital) and the lagged levels of each variable. As suggested by Blundell and Bond (2000), the use of lagged difference as instrument to estimate the equation in first-difference and then at levels gives a superior argument for the system GMM. The system GMM outperforms the dynamic model. This estimator comparatively produces the least bias and highest precision when the series is persistent. This study, adopt the System Generalized Method of Moment (GMM) dynamic panel estimation because it is capable of correcting for unobserved country heterogeneity, endogeneity,

omitted variable bias, and measurement error (Bond, Hoeffler, & Temple, 2001) which are normally involved in studies of this nature. This estimator comparatively produces the least bias and highest precision when the series is persistent. Moreover, the estimator have the best small sample properties in terms of sample bias and precision (Blundell & Bond, 1998) and that makes it a more reliable econometric tool of analysis for this paper.

As mentioned earlier the study investigates the trade-induced environmental effect by estimating system GMM. In the GMM estimations, the Sargan and the Arellano-Bond test for AR (1) and AR (2) are post estimations which indicate the model fitness. Sargan and Hansen test for over-identifying restrictions indicate the overall validity of the instruments with a null hypothesis that all instruments as a group are exogenous. Hence a greater p-value for both the Sargan and Hansen test, often above 5 percent significant level, is desirable. Arellano-Bond test for AR (1) and AR (2) access the null hypothesis that the error term of difference equation is not serially correlated. It is however expected that the AR (1) will reject the null due to reoccurrence of the first lag of the variables in the differencing process. The second order Arellano-Bond test indicates that there is no significant autocorrelation at levels. Thus, it is desirable if the p-value is above the 5 percent significant level. To ensure robustness of the estimations, the Generalised Least Square (GLS) estimation was carried out.

Robust Check

In finding the appropriate estimation approach for the robustness check for a panel data, the properties of the error term needs to be considered. The fundamental thing is whether the unobserved individual-specific effects are independent of the

regressors or correlated(Croissant & Millo, 2008). Usually we assume that the idiosyncratic error term ($\mathcal{E}_{it}$) is well-behaved and is not correlated to the regressors and the individual-specific error (e_i)(Constantini & Monni, 2008). But, the individual difference (individual-specific error) may be either correlated or independent of the regressors. The ordinary least square (OLS) would be inconsistent, if the individual error is correlated. In this case, the e_i is treated as a further set of N parameters to be estimated, where time invariant parameters are assume constant. This form of estimation is called the fixed effect. If the unobserved individual-specific effects/differences are independent of the regressors, then the random effect is estimated. The Hausman test is carried out on the fixed and random effect estimators to decide which best serve the data.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents the econometric estimations and results discussion. This chapter is divided into five sections. Aside this introductory section, the second section gives a descriptive statistics of the data used for the research. The fourth section presents the results on each of the four models estimated, in terms of carbon dioxide (CO2), methane (CH4), nitrogen oxide (N2O) and the fluorinated gases (F-gases). Section five present the robustness check.

4.2 Descriptive Statistics of Data

Table 1 presents the descriptive statistics which includes the number of observation, mean, standard deviation, minimum and maximum values of the variables ranging from 1990 to 2014. The data as shown in table 1 has different observations for each of the variables. This is mainly because the panel is unbalanced. The variables are expressed in natural logarithm in order to eliminate the high skewness presented by the raw data. As shown in Appendix G and H, the distributions of the variables are badly skewed. Thus, to normalized the data and also correct the issues of heteroskedasticity, the researcher takes the log transformation of the data.

Carbon dioxide, methane and nitrogen oxide emissions are scattered around the geometric mean. The dispersion in F-gases is highly closed around the geometric mean as compare to the other variables. Trade openness seems fairly dispersed. Africa's Average GDP per capita and Africa's Average capital-labour ratio are highly dispersed around the geometric mean. Also, FDI appear to be scattered around the geometric mean.

Table 1: Descriptive Statistics

Variable	Number of Observation	Mean	Standard Deviation	Min	Max
ln Carbon Dioxide	1,081	7.688	1.878	3.245	13.08
ln F-gases	1,098	6.626	7.965	-33.96	14.26
ln Methane	1,150	8.634	1.743	2.88	12.15
ln Nitrous Oxide	1,150	7.852	1.941	2.571	12.06
lnGDP per Capita	1,236	6.65	1.129	4.242	9.675
ln Capital-labour Ratio	881	5.149	1.362	1.458	9.159
ln Trade Openness	1,194	4.201	0.499	2.406	6.276
lnFDI	1,151	18.2	2.477	2.374	23.17
Environmental Regulation	366	3.055	0.542	2	4
Africa's Average Capital-labour Ratio	1250	336.465	895.167	-433.838	9503.729
Africa's Average GDP per Capita	1236	1635.279	2545.544	69.57919	15912.14

Source: Author's Estimation

The average strength of Africa's environmental regulation measured by the environmental policy and institution index is 3.055, compare to the upper limit of 6. This shows that environment regulations are averagely stringent in most Africa countries. In other word, we can say environmental regulations are somewhat lax.

4.3 Estimation Results and Discussion

This section presents the system GMM estimation and discussion for all four categories of GHGs. Before proceeding with discussions, it is important to point out that the validity and reliability of the models were ascertain using the AR(1) and AR(2), Hansen and the Sargan tests. The standard errors are in the parentheses. *** represent significant at 1% level or 99% confidence level, ** represent 5% significant level or 95% confidence level, whereas * represent 10% significant level or 90% confidence level.

4.3.1 Results and Discussion on Carbon Dioxide

As shown in table 2, the Sargan, Hansen and second order Arellano-Bond test indicates that there is no significant autocorrelation. All three tests imply that the instruments used in the estimations are valid and the error terms are not serially correlated.

Table 2: Emission Equations of CO_2

Variables	System GMM
ln lagged Carbon Dioxide	0.98098*** (0.009)
ln lagged GDP per Capita	-1.30595*** (0.375)
ln GDP per Capita Squared	0.55304 (0.419)
ln Trade Openness	1.78622** (0.682)
ln Capital-labour Ratio	1.45506** (0.615)
ln Capital-labour Ratio Squared	-0.52089** (0.216)
ln Trade Openness*Relative GDP per Capita	-1.90198** (0.708)
ln Trade Openness*Relative GDP per Capita Squared	1.06841** (0.450)
ln Trade Openness* Relative Capital-labour Ratio	-1.47282** (0.628)
ln Trade Openness* Relative Capital-labour Ratio Squared	0.52205** (0.220)
ln FDI* Relative Capital-labour Ratio*Relative GDP per Capita	-0.00070 (0.007)
Environmental Policy and Institution	0.02566 (0.018)
Constant	-0.68929 (3.803)
Arellano-Bond test for AR(1): z = -2.48 Pr > z = 0.013	
Arellano-Bond test for AR(2): z = 1.00 Pr > z = 0.318	
Sargan test: chi2(77) = 75.70 Prob> chi2 = 0.553	
Hansen test: chi2(64) = 1.46 Prob > chi2 = 0.483	

Source: Author's Estimation

From table 2, the lagged value of carbon dioxide recorded a statistically significant positive relationship with the dependent variable at the 99% confidence level. This suggests the past levels of carbon dioxide emission influence the current levels of emission. This result is consistent with the supposition of Forster, et al (2007), that carbon dioxide emitted today stay longer in the atmosphere up to a century while the remaining 20 percent could linger on up to about 800 years from time of emisson.

Income Effect

The income effects which invariably captures the scale-technique effect as shown in Table 2 is negative and statistically significant. This indicates a reduction in CO_2 emissions as income increases. This finding is consistent with the assertions of Bahagawati (1993) and Beckerman (1992) who argued that income has improving effect on evironmental quality. This result on the scale-technique effect does not support that of Cole and Elliot's (2003a) who found the scale-technique effect to be positive at a 99% confidence level and the square of the scale-technique effect to be negative but insignificant. The result on the square term suggest that economic growth does not significantly account for rising CO_2 emission which is consitent with the findings of Lin et al (2016) who argue that economic economic growth does not significantly cause CO_2 emissions in Africa.

In all, we are unable to validate the inverted U-shaped income-pollution relationship.The plausible reason for the non-observance of the income- pollution effect could be attributed to the fact that most Africa countires are raw material led economies who trade largely in "non-industrial product". This type of trade has it comparative advantage in labour-intensive methods and do not require high energy

use, which according to Cole and Elliott (2002) is environmentally cleaner than capital-intensive productions.

Direct Trade Effect

The direct effect of trade openness on carbon dioxide is found to be statistically significant with a positive sign, contrary to the theory of Antweiler et al (2001). This result is consistent with that of Cole and Elliot (2003a) and Managi, et al. (2008) who found evidence of CO_2 emissions increasing with trade innon-OECD countries. This findings suggest that emission of carbon dioxide is embodied in international trade (OECD, 2015), due to the carbon-base fuel such as coal, natural gas, oil and gasoline and biomass used in production and consumption in the region.

Direct Composition Effect

In terms of the direct composition effect which measures comparative advantage and proxied by capital-labour ratio, a significantly positive sign was found. This evidence generally supports the results of Cole and Elliott (2003a) and that of Managi, et al. (2008) for non-OECD countries.

Factor Endowment Effect

As predicted by theory, the indirect composition effect captured by the interaction term between trade openness and country's relative capital-labour ratio is found to be negative at 99% confidence level whereas the square term recorded a statistically significant positive sign. This result corroborate the factor endowment effect supposition in equation (3). As already established, countries with low capital-labour ratio experience declining levels of pollution with increasing trade openness.

This is the characteristic of most Africa countries and as such, this result is not surprising. However, the trade-induced CO_2 emission will fall to a threshold point and begin to rise. This is consistent with theory, as capital intensity in production increases with increase trade openness, emissions will invariably increase.

Environmental Regulation Effect

Moving on to second leg of the indirect or trade-induced composition effects as specified in equation (3), the interaction between trade openness and country's relative per capita income (ORG) produced a statistically significant negative effect whereas the square term give a significant positive sign. This shows that environmental regulation effect takes place in a counterintuitive way, contrary to the above supposition in equation (3). Instead of emission increasing with trade openness due to the low income status of most Africa countries, emissions rather decreases. However, this fall in CO_2 continues to a threshold point and begins to rise, thus giving a U-shape relationship. This situation we are unable to explain and may require further investigation.

However, a quick look at the behaviour of the income effect suggest that income drags trade-induced emissions down to a point and thereafter any increases in trade openness pulls emissions up. This go to affirm our initial supposition of Africa being a raw material trading region as such initial trade-induced CO_2 emission is relatively small and increases with increasing level of industrial activities. Moreover, environmental regulation institutions and policy indicator is statistically insignificant. Suggesting that the fall in emission indicated by the composition effects does not necessarily reflect a case of stringent environmental regulations. It could mean that

production processes are less pollution intensive by their very nature due to the low-capital intensity of production at the initial phase of economic growth.

In summary, the study found that income effect impedes CO_2 emissions whereas the effect of trade openness is seen to be increasing CO_2 emission suggesting the dominace of positive composition effect over the negative scale-technique effect.The trade-induced composition effect show rather an interesting result, whereby instead of environmental regulation effect opposing factor endowment effect, they both move in the same direct. This situation is probably because environmental quality is not yet a normal good for Africa countries. In other words, income has not increase to the point where citizens would be willing to pay for abatement cost.

The direct/overall effect of trade openness was not zero as predicted by equation (3), rather, it assumed a statistically significant positive sign. Given that the overall effect of trade openness is decomposed into scale-technique and composition effect (Antweiler et al, 2001), the results obtain by adding scale-technique to the composition effect (see, table 2) generally corroborate the sign on the direct trade effect, which suggest that free trade is detrimental to the environment. However, we might want to interpret these results with care considering that factor endowment effect and environmental regulation effect which are supposed to be opposing each other are seen to be moving in the same direct.

4.3.2 Results and Discussion on F-gases

As shown in table 3, the Hansen, Sargan and the second order Arellano-Bond tests indicate that there is no significant autocorrelation and all the instruments used in the estimations are valid and the error terms are not serially correlated. The lagged value

of F-gases reports a statistically significant positive relationship with the dependent variable at the 99% confidence level. This suggests the past levels of f-gas emission influence the current levels of emission.

Table 3: Emission Equation for F-gases

Variables	System GMM
ln lagged F-gases	0.93577***
	(0.034)
ln lagged GDP per Capita	-0.00627
	(1.234)
ln GDP per Capita Squared	-2.68739
	(1.780)
ln Trade Openness	12.41635**
	(5.145)
ln Capital-labour Ratio	13.94932**
	(5.929)
ln Capital-labour Ratio Squared	-5.60212**
	(2.357)
ln Trade Openness*Relative GDP per Capita	-12.94011**
	(5.306)
ln Trade Openness*Relative GDP per Capita Squared	9.04801**
	(3.737)
ln Trade Openness* Relative Capital-labour Ratio	-14.07504**
	(5.930)
ln Trade Openness* Relative Capital-labour Ratio Squared	5.60643**
	(2.347)
FDI* Relative Capital-labour Ratio*Relative GDP per Capita	0.08846*
	(0.046)
Environmental Policy and Institution	-0.05795
	(0.049)
Constant	23.81218
	(15.404)
Arellano-Bond test for AR(1): z = -2.06 Pr > z = 0.040	
Arellano-Bond test for AR(2): z = -1.10 Pr > z = 0.264	
Sargan test: chi2(86) = 69.47 Prob > chi2 = 0.904	
Hansen test: chi2(64) = 1.46 Prob > chi2 = 0.355	

Source: Author's Estimation

The Income effect

From table 3, the scale-technique effect is positive but insignificant. This result may be due to the fact that emissions of f-gases in most Africa countries largely originates from consumption not direct production processes. As such requires no technology effect or leaves no extraction effect. This result corroborate the non-existence of a statistically significant Kuznets curve for f-gases.

Direct Trade Effect

Actual trade openness is found to be significantly positive. This suggest that emission of f-gases increase in respond to trade openness. This should be expected since most of Africa's f-gas emissions originate from the importation of used fridges and automobiles, which are at a higher rate of emitting f-gas during the consumption process. Unfortunately for most Africa countries, consumption of these products is skewed toward "second-hand". In essence, increased trade openness invariably results in increased f-gas emissions.

Direct Composition Effect

In terms of the direct composition effect, a statistically significantpositive sign was found. This suggest thatK/L which is a measure of country's comparative advantage (for that matter composition effect) increases f-gases emissions.

Factor Endowment Effect

As characteristics of the countries under observation, the low K/L is expected to induce a fall in pollution in response to trade openness. This theory is corroborated by the result on the interaction term between trade openness and country's relative

capital-labour ratio (which is negative at 95% confidence level) and its square term (which is positive at the 95% confidence level). These results validate the conditions for the factor endowment effect as predicted in equation (3). Thus, increased capital-labour ratio in the face of increased freer trade induce a fall in f-gas emission to a point and thereafter raises emissions.

Environmental Regulation Effect

Furthermore, when trade openness is interacted with country's relative per capita income (ORG), a statistically significant negative effect is found, whereas the square term is significant with a positive sign. This shows that the environmental regulation effect take place in a counterintuitive way, contrary to the above supposition in equation (3). Instead of emission increasing with trade openness due to the low income status of most countries, emissions rather decreases. However, this fall in f-gas continues to a threshold point and begins to rise, thus giving a U-shape relationship instead of the expected inverted U-shape. This situation we are unable to explain and may require further investigation. However, this could partly be attributed to the fact that, only recently do most households see owning automobiles and fridges in Africa as necessities. Motor vehicles were introduced to the Africa continent by the colonial system and even then were seen as a thing for the elite (see, Gewald, 2005). The take-off phase could be explained by the recent improvement in living standards where these commodities are now seen as necessities for the average households. Even that, most household still consume the "second hand" which are higher emitters of f-gases.

The sign on the environmental policy and institution term is negative but statistically insignificant. This suggest that role of environmental policy and

institutions do not significantly reduce f-gas emission or they are inadequate. As such, the falling phase of f-gas emissions due to the composition effects recorded above, could not necessarily be because of stringent environmental regulations but rather as a result of low consumption at the initial phase of economic growth. In essence, the fall and rise of f-gas emission could not have been cause by stringency or laxity of environmental regulations. This result generally supports Toby (1990) who found environmental regulations to be insignificant at influencing trade, for that matter emission.

Generally, we are unable to validate asignificant income-pollution effect (Kuznet curve) for f-gases but it is worth noting that the positive composition is strong enough to cause the direct trade effect to be positive. This shows that trade is harmful to the environment in relation to f-gas. Also the trade-induced f-gas emissions originated from both factor endowment effect and environmental regulation effect. Instead of the two forces opposing each other as predicted, the moved in the same direction.

4.3.3 Results and Discussion on Methane

As shown in table 4, the Hansen, Sargan and second order Arellano-Bond test produce p-values that are more than the 5% significant level, which is desirable. This implies that the instruments used in the estimations are valid and the error terms are not serially correlated. The lagged value of methane records a statistically significant positive relationship with the dependent variable at the 1% significant level. This suggests that past levels of methane emission influence the current levels of emission. This result is consistent to the supposition of Forster, et al. (2007), who argue that methane emitted today take about a decade to leave the atmosphere.

Table 4: Emission for Methane

Variables	System GMM
ln lagged Methane	0.96880***
	(0.016)
ln lagged GDP per Capita	0.11080
	(0.354)
ln GDP per Capita Squared	-0.05971
	(0.478)
ln Trade Openness	1.47072
	(1.268)
ln Capital-labour Ratio	1.71298
	(1.171)
ln Capital-labour Ratio Squared	-0.84809**
	(0.391)
ln Trade Openness*Relative GDP per Capita	-1.34897
	(1.441)
ln Trade Openness*Relative GDP per Capita Squared	0.66279
	(1.008)
ln Trade Openness* Relative Capital-labour Ratio	-1.72561
	(1.193)
ln Trade Openness* Relative Capital-labour Ratio Squared	0.86041**
	(0.400)
ln FDI* Relative Capital-labour Ratio*Relative GDP per Capita	0.01410
	(0.008)
Environmental Policy and Institution	-0.00226
	(0.017)
Constant	0.26547
	(3.104)
Arellano-Bond test for AR(1): z = -2.22 Pr > z = 0.027	
Arellano-Bond test for AR(2): z = -0.59 Pr > z = 0.544	
Sargan test: chi2(89) = 88.81 Prob > chi2 = 0.518	
Hansen test: chi2(88) = 1.46 Prob > chi2 = 0.749	

Source: Author's Estimation

The Income Effect

The lagged per capita income and its square are found to be statistically insignificant. In essence income growth does not significantly influence the emission

of methane. This result corroborate the non-existence of a statistically significant Kuznets curve for methane.

Direct Trade Effect

The actual effect of trade openness is found to be statistically insignificant. It is unclear why trade does not significantly increase emission of methane. Considering that methane is largely emitted from one of the major productive sectors (agriculture sector) of most Africa countries, one would have expected that trade will induce emission of methane. However, EPA (2016) reported that – aside other source like livestock, some agriculture practices, and decay of organic waste– methane is produced during the production and transportion process of coal, natural gas and oil. This form of methane emission is rather very localised and may not significantly feed into group level trade-induced emissions since only two Africa countries (South Africa and Zimbabwe) are recognise by International Energy Agency as having coal reserves. Nigeria, on one hand, though producing oil, its coal reserves are untapped.

Direct Composition Effect

The direct composition effect is statistically insignificant with a positive sign. The statistically significant negative sign reported for the square term suggest that methane emissions falls at some point in response to increased capital-labour ratio. However, it is unclear whether the decrease in emission due to this length of the composition effect will be enough to offset the increasing pollution from the scale-technique effect; if the positive sign on the scale-technique effect is anything to go by.

Factor Endowment Effect

The indirect composition effect captured by the interaction term between trade openness and country's relative capital-labour ratio produced a positive statistically insignificant sign whereas the square term recorded a statistically significant negative sign. This result fail to corroborate the factor endowment supposition in equation (3).

Environmental Regulation Effect

The interaction between trade openness and country's relative per capita income (ORG) produced a statistically insignificant negative sign, whereas the square term give an insignificant positive sign. Thus, we are unable to validate the environmental regulation effect. Moreover, the environmental policy and institutions indicator produced a statistically insignificant negative sign. Suggesting that any fall in emission of methane resulting from the composition effect above, does not reflect stringency of environment regulations.

Generally, we are unable to substantiate the existence of a Kuznets curve for methane, whereas the supposition of a trade induced-composition effect of methane emissions could also not be validated. There is, however, some polluting impact of the factor endowment effect, but the results are inconclusive.

4.3.4 Results and Discussion on Nitrous Oxide

As shown in table 5, the Hansen, Sargan and the second order Arellano-Bond test produce p-values greater than 5 percent significant level, which is desirable. All three tests indicate that the instruments used in the estimations are valid and the error terms are not serially correlated. The lagged value of nitrous oxide is statistically significant at the 99% confidence level with a positive sign. This suggests the past

levels of nitrous oxide emission influence the current levels of emission. This result is consistent with the supposition of Forster et al (2007) that nitrogen oxide emitted today stay in the atmosphere for about a century.

Table 5: Emission Equation for N_2O

Variable	System GMM
ln lagged Nitrous Oxide	0.96676***
	(0.013)
ln lagged GDP per Capita	0.42979
	(0.743)
ln GDP per Capita Squared	-0.49531
	(0.952)
ln Trade Openness	4.34306**
	(2.014)
ln Capital-labour Ratio	4.60278*
	(2.175)
ln Capital-labour Ratio Squared	-2.03574**
	(0.733)
ln Trade Openness*Relative GDP per Capita	-4.30207*
	(2.143)
ln Trade Openness*Relative GDP per Capita Squared	2.42349
	(1.610)
ln Trade Openness* Relative Capital-labour Ratio	-4.62810*
	(2.208)
ln Trade Openness* Relative Capital-labour Ratio Squared	2.05288**
	(0.746)
ln FDI* Relative Capital-labour Ratio*Relative GDP per Capita	0.01903*
	(0.010)
Environmental Policy and Institution	-0.01734
	(0.031)
Constant	1.59997
	(5.862)
Arellano-Bond test for AR(1): z = -2.30 Pr > z = 0.022	
Arellano-Bond test for AR(2): z = -0.20 Pr > z = 0.824	
Sargan test: chi2(89) = 88.23 Prob > chi2 = 0.537	
Hansen test: chi2(64) = 1.46 Prob > chi2 = 0.962	

Source: Author's Estimation

The Income Effect

The scale-technique effect is statistically insignificant with positive sign. Likewise, the square of the per capita income, but the sign is negative. As such, we are unable to validate the income-pollution effect (Kuznets curve).

Direct Trade Effect

The direct effect of trade openness on nitrous oxide is statistically significant with a positive sign. This imply that increase trade openness invariably result in increased nitrous oxide emission. This finding on N_2O supports the results of Frankel and Rose (2005) and Cole and Elliot (2003a). This is largely due to the fact that most Africa countries are agriculture led economies. Being an agrarian region and with agriculture contributing over 70% of total N_2O emissions as at 2010 (see, IEA, 2012), it is expected that increased trade will induce an increase in N_2O emissions.

Direct Composition Effect

In terms of the direct composition effect (K/L), a statistically significant positive sign was found. Therefore, as Africa increases trade in these agriculture-base commodities, N_2O emission increases due to direct factor endowment effect.

Factor Endowment Effect

Interacting trade openness and country's relative capital-labour ratio produce a negative and significant sign at 90% confidence level, whereas the square term produced a positively significant sign at 95% confidence level. This signifies a fall in nitrous oxide emission due to the factor endowment (K/L) effect. However, this

decline in emission is hardly sustained as N_2O emissions rise afterwards. The results corroborate the factor endowment theory postulated in equation (3).

The result on the interaction between FDI, Relative Capital-labour Ratio, Relative GDP per capita produce a statistically significant positive sign, which is contrary to the expected sign. The probable reason for this findings is that FDI inflow into the African region does not contribute significantly to the diffusion of clean technology as purported (see, Dasgupta et al., 2002; Dean, 2004). The results are consistent with the findings of Pao and Tsai (2011) who argued that FDI inflows to developing countries may rather raise emissions.

Environmental Regulation Effect

Furthermore, interacting trade openness with country's relative per capita income (ORG) produce a statistically significant negative sign at 90% confidence level whereas the square term is positive but insignificant. This implies that improvement in income resulting from trade may try to offset the trade-induced nitrous oxide emission but only marginally. In essence, we are unable to validate the environmental regulation effect. Moreover, environmental policy and institution effectiveness is found to be statistically insignificant. In other words, the environmental policy and institutions do not respond adequately to emission growth. Thus, any fall in emission of nitrous oxide resulting from the composition effect above, does not reflect stringency of environment regulations.

Generally, lumping the positive composition effect and the positive scale-technique effect gives a blear picture for Africa's environmental quality in relation to nitrous oxide. This is consitent with the realities in Africa, considering it's an agriculture-based region and is ranked among the regions in world trade producing

three-quarter of global nitrous oxide with a percentage point of 19 next to China (18%) (see IEA, 2012). Inspite of the insignificant income effect, the positive composition effect is strong enough to produce a positive sign fordirect trade openness. This signify that trade is harmful to the environment in relation to N_2O. The trade-induced environmental effect originates largely from the factor endowment effect.

4.3.5 Robust Check

This section presents the robust check for each of the econometric model presented above. Generally, when working with time series data, the stationarity test is relevant and to ensure robustness of the results, two unit root test were conducted. They are Fisher's Augmented Dickey-Fuller (ADF) and Im-Pesaran-Shin (IPS) as shown in table 6.Both test produce p-values that are generally less than the 5% significant level, except for relative GDP per capita, which recorded a 10% significant level in the IPS test. This implies that both tests generally corroborate the rejection of the null hypothesis that all the panels contain unit roots. In essence, the results suggests that all variables are integrated at order [I(0)]. In other words, the variables are stationary at levels. By implication the long run relationships between each of the four emissions and independent variables could be estimated without issues of spurious or unrelated regressors (see, Costantini and Martini, 2009).

Table 6: Unit Root Test

	Fisher's ADF		IPS	
Variable	Statistics	P-values	Statistics	P-values
Carbon Dioxide	1.7863	0.0370	-1.8826	0.0299
F-gases	19.3402	0.0000	-11.6561	0.0000
Nitrous Oxide	10.1636	0.0000	-8.2915	0.0000
Methane	10.9223	0.0000	-7.8062	0.0000
GDP per capita	1.9568	0.0252	-2.6969	0.0035
Relative GDP per Capita	17.0546	0.0000	-1.2358	0.1083
Trade Openness	8.7528	0.0000	-2.5427	0.0055
Capital-labour Ratio	10.4161	0.0000	-10.2190	0.0000
Relative Capital-labour ratio	22.5955	0.0000	-8.7022	0.0000
Foreign Direct Investment	12.8853	0.0000	-8.2018	0.0000
Environment Policy and Institution	17.1213	0.0000	-0.1545	0.0000

Source: Author's Estimation

Results and Discussion

The results of the general least square (GLS) estimations for the robustness check are included herein. It is worth noting that the decision as to which GLS estimator to use for the robustness check was solely done based on the results from the Hausman test. Appendix C presents the results of the Hausman test for CO_2 emissions in favour of the random effect model; the results of the Hausman test for N_2O emissions also favours the random effect model (Appendix D); the same goes for f-gases as shown in Appendix F. However, the Hausman test for methane (see Appendix E) favours the fixed effect model. The results of each of the models are compounded in table 7.

Table 7: Models of Robustness Check

Variables	Carbon Dioxide	Nitrous Oxide	Methane	F-gases
ln lagged GDP per Capita	-0.28558	-1.38899**	-0.48513	2.65175
	(0.386)	(0.572)	(0.333)	(2.344)
ln GDP per Capita Squared	-0.16444	0.40679	0.45222	-2.15246*
	(0.324)	(0.921)	(0.629)	(1.147)
ln Trade Openness	1.59580	4.38037***	2.38628*	3.14339
	(0.991)	(1.390)	(1.357)	(3.145)
ln Capital-labour Ratio	1.51688**	3.18693**	1.18208	5.68027*
	(0.669)	(1.557)	(1.013)	(3.146)
ln Capital-labour Ratio Squared	-0.23459	-1.27939**	-0.42895*	-3.16397**
	(0.235)	(0.510)	(0.211)	(1.348)
ln Trade Openness*Relative GDP per Capita	-2.20130**	-5.20399***	-2.27198	-4.82353
	(0.911)	(1.399)	(1.368)	(3.236)
ln Trade Openness*Relative GDP per Capita Squared	1.44133**	2.21800	0.75505	2.59261
	(0.563)	(1.366)	(1.160)	(2.056)
ln Trade Openness* Relative Capital-labour Ratio	-1.54324**	-3.38456**	-1.27113	-5.63244*
	(0.688)	(1.614)	(1.027)	(3.114)
ln Trade Openness* Relative Capital-labour Ratio Squared	0.20611	1.32492**	0.44047**	3.24017**
	(0.238)	(0.526)	(0.205)	(1.357)
ln FDI* Relative Capital-labour Ratio*Relative GDP per Capita	-0.00500	-0.00839	0.00327	0.10460**
	(0.023)	(0.033)	(0.025)	(0.047)
Environmental Policy and Institution	0.02413	-0.12116	-0.04864	-0.19556
	(0.109)	(0.119)	(0.058)	(0.178)
Constant	-1.87409	-1.85213	2.84667	10.78586
	(3.333)	(12.324)	(7.618)	(13.934)

Source: Author's Estimation

Generally, the results of the GLS shown in table 7 for each of the gases corroborates the results in their respective system GMM estimations. Base on this findings we can safely conclude that the results of this study are fairly robust. Nontheless, the system GMM remain relatively superior to the GLS estimators due to the problem of spatial heterogeneity and spatial dependence (see Appendix E and F)as well as the endogeneity present in the data.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter presents the concluding parts of the entire study. It is divided into five sections. Aside this introductory section, section two gives the summary of the estimation results. The third section presents the conclusion, whereas the policy recommendations are included in the fourth section. The last section presents the limitations to the study.

5.2 Summary

In line with the debate on economic growth and environmental pollution nexus, many researchers including Antweiler et. al (2001), Bhagawati (1993); Cole & Elliott (2003a)and Elmarzougui et. al (2016) have examined the link between environmental pollution and international trade which has a strong positive link with economic growth (Edwards 1992; Sachs & Warner 1995; Krueger 1997; Frankel & Romer, 1999). The arguments in literature explaining the interrelationship between international trade and the environment have been drawn between good and bad. Whiles Managi (2004) argues that trade is harmful to the environment, due to the high quest to improve income through trade, Antweiler, et al., 2001 argued that trade is good for the environment as it is believed that income is a preconditions for improving the environment (Bhagawati, 1993).

In the midst of this inconclusive argument, it is also not well established if trade-induced emissions originate from differences in countries' comparative advantage due to the factor endowment effects and environmental regulation effect. This give raise to the research questions as to; whether increased income affect

environmental quality? What is the direct effect of trade on environmental quality? Do trade-induce emissions originate from differences in countries' comparative advantage due to the factor endowment effect and/or environmental regulation effect? What policies are needed to ensure that trade openness does not deteriorate environmental quality? In attempts to find answers to these questions, this study employed the System GMM econometric technique and found the following results:

In relation to the effect of income on the environment which was captured by the scale-technique effect and it square term, a negative sign was found at 99% confidence level for CO_2. Suggesting that increased income induces a fall in CO_2 emissions. But in the case of f-gases, CH_4 and N_2O, the scale-technique effect is positive but statistically insignificant. In all, we are unable to validate the existence of the inverted U-shaped income-pollution effect (Kuznets curve) for each of the pollutants.

The direct/actual effect of trade openness on CO_2, f-gases and N_2O was found to be statistically significant with a positive sign, except for CH_4, which was positive but statistically insignificant. In essence, emission of CO_2, f-gases and N_2O increases with greater openness of trade.

The trade-induced composition effect was positive for CO_2, N_2O and f-gases. A similar positive composition effect was found for CH_4 but it is statistically insignificant. This suggests that the composition effect causes emission of CO_2, f-gases and N_2O to increase.

The factor endowment effect captured by the interaction term between trade openness and country's relative capital-labour ratio and its square term is validated for CO_2, f-gases and N_2O. This implies a fall in emissions in response to increased trade openness up to a point and rises thereafter. Suggesting that the factor endowment

effect accounts for trade-induced emission of all three gases. Similar results were found in the case of CH_4 but is statistically insignificant.

The environmental regulation effect captured by the interaction term between trade openness and country's relative per capita income and its square term was not validated for all four gases. In the case ofCO_2, and f-gases the environmental regulation effect took place in a counterintuitive way, contrary to the above supposition in equation (3). Instead of opposing factor endowment effect, environmental regulation effect moved along with it. The results for N_2O and CH_4 is inconclusive. Aside N_2O, where environmental policy and institution effectiveness was found to be prohibiting emissions barely at the 90% confidence level, environmental policy and institution did not respond towards the other gases. In other words, the laxity of environmental regulations and institutions does not significantly influence the emission of f-gases, CH_4 orCO_2. This explains why the positive composition effect dominates scale-technique effect for GHGs considering that the cost of environment does not significantly increase the cost of production of the polluting firms.

Finally, accounting for regional differences is instrumental in ascertaining the true impact of trade-pollution interrelationship. It was found that the past levels of GHGs emission significantly increase the current level. The natures of these global emissions are such that current levels are influenced by the past emission; as such estimations that do not account for this dynamics may be flawed. For example, as mentioned earlier, CH_4 emitted today takes about a decade to leave the atmosphere, N_2O about a century, same for about 80 percent of CO_2 but the rest of the 20 percent is left behind for about 800 years after emission. Therefore, econometric techniques that do not account for this effect may not depict the true picture.

5.3 Conclusion

Throughout, the discussion in the literature about the interrelatedness between trade openness and pollution, three perspectives came up. The first supposition is that free trade is beneficial to the environment (Antweiler, et al, 2001; Bhagawati, 1993). The second utterly contradict the first, that free trade is harmful to the environment (IPCC, 2001; Dean, 1992a; Managi, 2004). Later, the unifying supposition was invoke, which states that trade initially pollutes but subsequently improves the environmental quality (Dean, 1999; Strutt & Anderson, 2000; Managi, et al, 2008).

However, this current study did not find sufficient evidences to support the inverted U-shaped relationship between income and pollution. But it does corroborate the supposition of Bhagawati (1993)that improvement in income is the precondition for improving environmental quality, as shown in the income effect obtain for CO_2. Nonetheless, greater trade openness is reported to have a deteriorating effect for the environmental quality in relation to CO_2, f-gas and N_2O.This trade-induced CO_2 and f-gas emission are reported to have originated largely from factor endowment effect. This results presupposes that *income elasticity of enviromental quality demand* in Africa may not be more than unitary as such there is not much pressure from citizens to improve environmental quality as income increases. In other words, income has not increased to the point where citizens would be willing to pay for abatement cost or advocate for stricter environmental regulation.

Another plausible reason for this alliance between the factor endowment effect and the supposed opposing environmental regulation effect could be attributed to the fact that most Africa countries have not experienced sustainable economic growth that would warrant stringent environmental regulations. Therefore, environment cost does not significantly affect production cost of polluting industries. If an economy finds it

difficult to sustain its rising economic activities, any attempt to grow faster at the early stages of development, especially when enviromental pollution is increasing, may prove counterproductive (Stern, 2003) and the improvement phase brought about by income may not exist.

5.4 Policy Recommendation

It is clear that emission of GHGs in Africa increases in response to trade openness. In order to effectively mitigate GHGs, policy will have to be tailored toward reducing instead of displacement of emissions. The "leakage" of GHGs resulting from pollution haven pressure will not yeild any global benefit. As such it is expected that policies would have to address the bigger picture, rather than attempting to optimise an individual regions performance in the fight against climate change.

For environmentally sustainable income growth, modification of production lines (or changing of production inputs) may prove to be more effective at reducing industrial emissions than the traditional improvement in energy use efficiency. Also, Africa as a developing destination of trade would have to critically examine the kind of trade partnerships it signs to, in order not to pose further challenge to the environmental performance. An example of such agreement is the on-going Economic Partnership agreement (EPA) between member states and the European Union (EU). It is apparent that countries in Africa needs to develop the human capacity to effectively and meaningfully take part in such trade negotiations and secure deals that are not environmentally challenging, particularly for the pollution intensive sectors like mining and industries.

Emission of f-gases is made pronounced by the increasing trade in used or "home use" electrical and electronic materials like fridges, automobiles in most

households in Africa. It is imperative that trade in these imported used gargets are banned. Countries, like Ghana, that have taken the led to implement this policy would have to do more to strictly enforce it. In other jurisdiction, import taxes on used automobiles should be high enough to deter domestic consumers from importing them.

In relation to carbon dioxide emissions, policies and practical steps of energy efficiency and conservation should be taken by industries and households. Countries like Ghana who has started the initiative of distributing LED bulbs to households and the replacement of old fridges should be encouraged to continue. If households, firms and communities reduce energy consumption, the benefit comes in a form of reduced utility bills which decreases the demand for the construction of new fossil-fueled energy generating plants. Research into workable carbon-free sources of energy should be undertaken (see, IPCC, 2014).

The agriculture related emission of methane and nitrous oxide could be reduced by adopting good farm practices such as substituting inorganic nitrogen fertilizer for organic fertilizers where necessary and matching fertilizers efficiently to plant needs (see, IPCC, 2014; UNEP, 2016). It is therefore recommended that agriculture extension officers carry out education on the best farm practices.

Furthermore, it is recommended that countries in Africa should take action to reduce emission by strengthening the necessary institutions in charge of ensuring environmental policy effectiveness and ensure that appropriate systems of monitoring, reporting and verifications are done (see, UNEP, 2016). These systems should be structured in such a way that any improvement or worsening of the environment performance due to any policy implementations are detected. The monitoring and verification systems of reporting emission should be transparent so as to ascertain the

actual levels of emission. As it is simple to isolate the level of energy efficiency or pollution emitted by a specific firm, it is difficult to determine that on regional bases. As such the various policy instruments (like carbon trading and voluntary carbon offset) aimed at reducing GHGs may turn to be counter proactive(see, IPCC, 2014). There is the need to separate the various policy instruments, or implement one at a time, in other to determine the improvement made by the introduction of specific instruments. Also trends in the external market conditions and capital stocks should be checked and policies implemented to check any pollution intensive capital trails.

Generally, the study investigated how international trade affects the environment or climate change. It is important to note that the relationship between trade and the climate is not one directional since the physical manifestation of climate change can affect the volume and pattern of trade flow. It is therefore recommended that subsequent studies take this reverse causal relationship into consideration.

5.5 Limitation of the Study

The study is limited in scope to six greenhouse gases including CO_2 and other anthropogenic GHGs (CH_4), N_2O and the F-gases (HFCs, PFCs and SF_6) and could not account for the impact of trade liberalisation on the other important pollutants like the sulfur dioxide and Biochemical Oxygen Demand due to limited data. The study was intended to cover all 54 independent Africa countries but South Sudan (being fairly young; after its separation from Sudan in 2014), Angola, Soa Tome and Principe and Somalia were also taken out because of insufficient data point.

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Appendix A: Hausman Test for CO_2

	Coefficients (b) fe	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnlG	-.2383594	-.2855764	.047217	.
lnG2	-.1953262	-.1644359	-.0308903	.
lnO	1.87	1.5958	.2741998	.
lnK_L	1.694296	1.516879	.1774165	.
lnlK_L2	-.2480621	-.2345885	-.0134736	.
lnORG	-2.220027	-2.201305	-.0187217	.
lnlORG2	1.604859	1.441332	.1635274	.
lnlORK_L	-1.708171	-1.543244	-.1649277	.
lnlOlRK_L2	.2175174	.2061085	.0114088	.
lnFDIRK_LRG	-.0154719	-.0050008	-.0104712	.
lnOGEG	.423468	.668127	-.244659	.0950111
ER	.0201916	.0241297	-.0039381	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 5.84
Prob>chi2 = 0.9238
(V_b-V_B is not positive definite)

Appendix B: Hausman Test for N_2O

	Coefficients (b) fe	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnlG	-1.493944	-1.388988	-.1049559	.
lnG2	.2170491	.4067928	-.1897437	.
lnO	5.905362	4.380371	1.524991	.
lnK_L	3.778416	3.186926	.5914905	.
lnlK_L2	-1.216985	-1.279387	.0624021	.
lnORG	-6.005299	-5.20399	-.801309	.
lnlORG2	2.981133	2.217996	.7631367	.
lnlORK_L	-3.959033	-3.384564	-.5744692	.
lnlOlRK_L2	1.252639	1.324924	-.072285	.
lnFDIRK_LRG	-.048239	-.0083886	-.0398504	.
lnOGEG	.0831972	.7674601	-.6842628	.2071198
ER	-.0409459	-.1211615	.0802156	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 11.84
Prob>chi2 = 0.4590
(V_b-V_B is not positive definite)

Appendix C: Hausman Test for CH_4

	Coefficients (b) fe	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnlG	-.4851322	-.514573	.0294408	.
lnG2	.4522196	.5170791	-.0648595	.
lnO	2.386283	1.43322	.9530632	.
lnK_L	1.182081	.7916594	.3904215	.
lnlK_L2	-.4289491	-.456506	.0275569	.
lnORG	-2.27198	-1.901552	-.3704283	.
lnlORG2	.7550459	.2836732	.4713727	.
lnlORK_L	-1.271126	-.9012028	-.3699233	.
lnlOlRK_L2	.440471	.4746997	-.0342287	.
lnFDIRK_LRG	.0032725	.0311805	-.027908	.
lnOGEG	.0571092	.6146201	-.5575109	.1050057
ER	-.0486422	-.095018	.0463759	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 28.19
Prob>chi2 = 0.0052
(V_b-V_B is not positive definite)

Appendix D: Hausman Test for F-gases

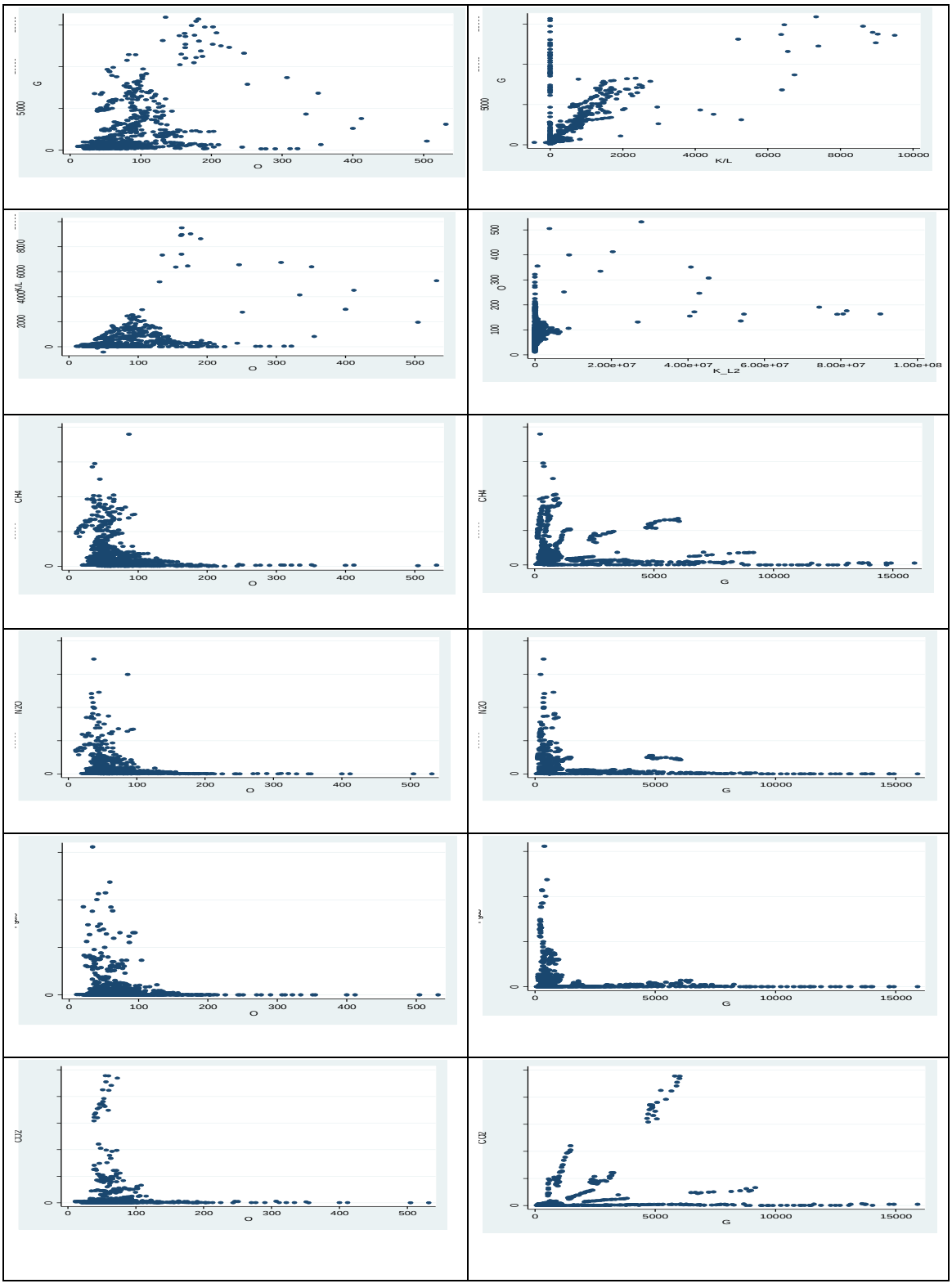
	Coefficients (b) fe	(B) .	(b-B) Difference	sqrt(diag(V_b-V_B)) S.E.
lnlG	3.149215	2.65175	.4974646	.
lnG2	-2.06787	-2.152463	.0845931	.
lnO	3.539374	3.143386	.3959878	.
lnK_L	6.109506	5.680266	.4292406	.
lnlK_L2	-3.239771	-3.163967	-.0758041	.
lnORG	-4.540018	-4.823527	.2835087	.
lnlORG2	2.825701	2.592605	.233096	.
lnlORK_L	-5.964028	-5.632441	-.3315873	.
lnlOlRK_L2	3.315178	3.240169	.075009	.
lnFDIRK_LRG	.052322	.1046002	-.0522782	.
lnOGEG	.4060055	1.104204	-.6981984	.383858
ER	-.2298457	-.1955611	-.0342846	.

b = consistent under Ho and Ha; obtained from xtreg
B = inconsistent under Ha, efficient under Ho; obtained from xtreg

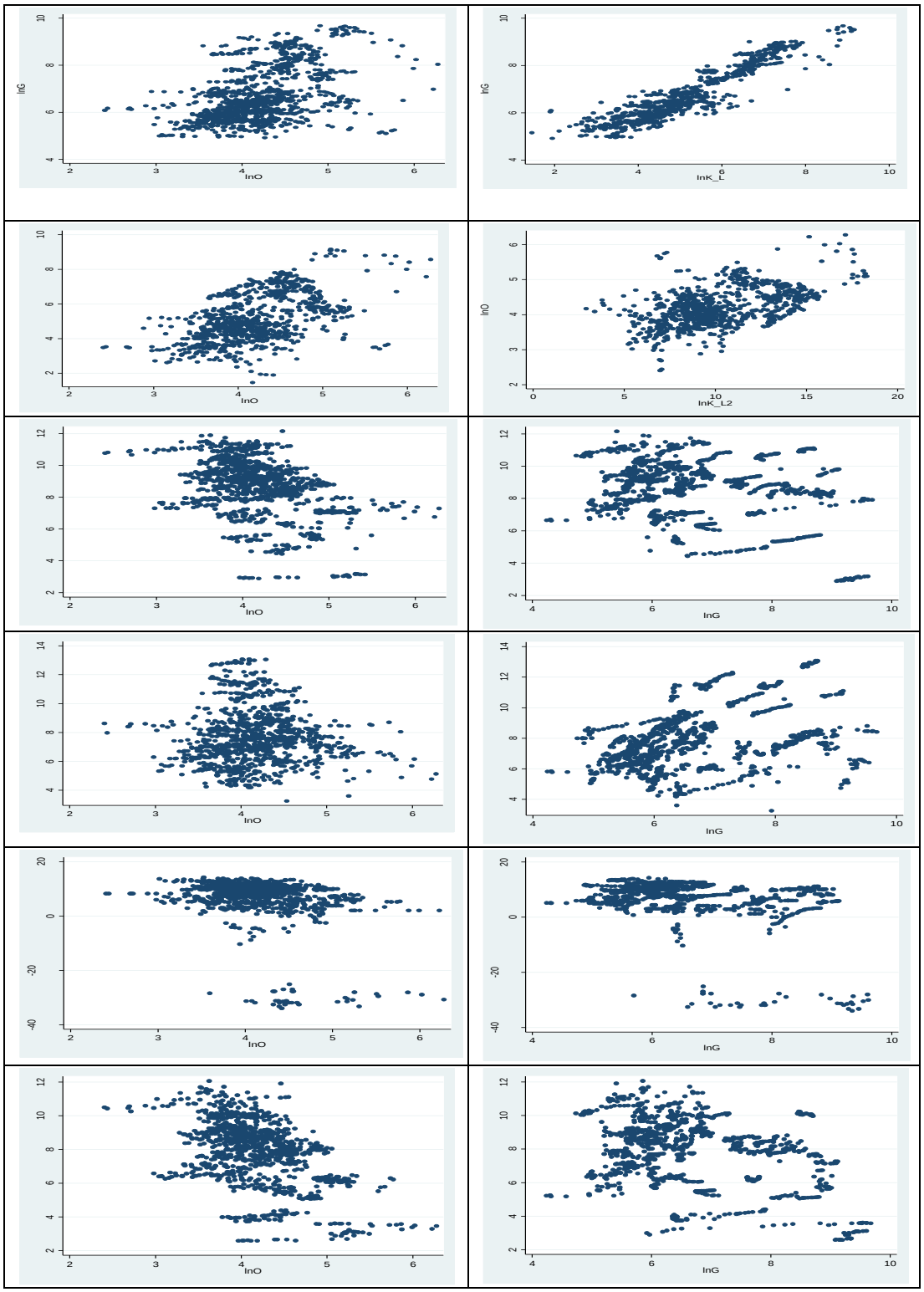
Test: Ho: difference in coefficients not systematic

chi2(12) = (b-B)'[(V_b-V_B)^(-1)](b-B)
= 1.11
Prob>chi2 = 1.0000
(V_b-V_B is not positive definite)

Appendix E: Scatter Plot Showing the correlation between the Variables



Appendix F: Scatter Plot Showing correlation between the log Variables



Appendix G : List of Countries Used in the Estimation

1. Egypt
2. Cameroon
3. Côte d'Ivoire
4. Gambia
5. Ghana
6. Nigeria
7. Senegal
8. Sierra Leone
9. Togo
10. Democratic Republic of Congo
11. Gabon
12. Sudan
13. Uganda
14. Kenya
15. Morocco
16. Mauritius
17. Botswana
18. South Africa

NO	COMMENTS	STUDENT'S RESPONSE TO COMMENTS
3(ii)	In light of the observations in (i), it might make sense to list the countries entailed in the panel dataset, which should not take much space because they are only 18.	The list of countries used in the panel estimation is included in Appendix G.
3(iii)	… However, it might be worth mentioning the limitations of the GMM in the estimation of dynamic panels with bigger time dimension than cross-section dimension.	The limitations of both the difference GMM and the system GMM are discussed in page 60 – 62; their respective advantages are also discussed.
4	… The candidate might wish to clarify some results eg. Table 2 shouldn't the variables be log (GDP) and {log (GDP)} squared?	Yes, the variable is *ln* GDP per Capita Squared instead of *ln* Square of GDP per Capita. The error is corrected.