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The Effect of Renewable, Non- Renewable and Biomass Energy Consumption and Economic Growth on CO_2 emission in Ethiopia

By

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The Effect of Renewable, Non- Renewable and Biomass Energy Consumption and Economic Growth on CO_2 emission in Ethiopia

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This is to certify that the thesis prepared by Zerebruk Gebrekristos, entitled: The Effect of Renewable, Non- Renewable and Biomass Energy Consumption and economic growth on CO_2 emission in Ethiopia and submitted in partial fulfillment of the requirements for the Degree of Master of Science (Natural Resource and Environmental Economics) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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ABSTRACT

The Effect of Renewable, Non- Renewable and Biomass Energy Consumption and Economic growth on CO_2 emission in Ethiopia.

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Recognizing the fact that the current reliance on traditional sources of energy is unsustainable, particularly from environmental grounds, the international community considers renewable sources of energy as a possible solution. But the effect of renewable and other sources of energy has to be evaluated in each country context separately. Hence the current study aim to examine the effect of consumption of energy from different sources (biomass, non-renewable and renewable) and economic growth on the emission of CO_2 (the major gas emitted from the energy sector) in Ethiopia (a country embarking to modern renewable energy sources) using Autoregressive Distributive Lag (ARDL) methodological framework. Results of unit root test shows that all the variables are non-stationary in their level forms and stationary in their first difference. Bound test for co integration shows the existence of long run co integrating relationship among the variables. From the results, biomass energy is found to positively affect emission of CO_2 in the long run. Non-renewable energy consumption also increases emission of the gas in both in the short run and long run significantly. In addition economic growth of the country under the study period leads to increase in emission of the gas. Therefore; it can be inferred that non-renewable (fuel) energy, biomass energy consumptions and the general economic growth of the country results in increase in emission of CO_2 in Ethiopia and are not in harmony with the country's objective of making the energy sector and the overall economic activity benign to the environment.

Key words: CO_2 emission, Biomass, Renewable and non-renewable energies, Autoregressive Distributive Lag, Ethiopia

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List of Acronyms

ADB:	African Development Bank
ADF :	Augmented Dickey-Fuller
AIC :	Akaiki Information Criteria
ARDL:	Autoregressive-Distributed Lag
BAU:	Business As Usual
BEC:	Biomass energy consumption
Co_2 :	Carbon di oxide
CO2eq:	Carbon di oxide equivalent
CRGE:	Climate Resilient Green Economy
EEA:	Ethiopian Economics Association
EIAGS:	Environment Impact Assessment Governance system
EKC:	Environmental Kuznets Curve
EPA:	Environmental Protection Authority
EU:	European Union
FDI:	Foreign direct investment
FDRE:	Federal Democratic Republic of Ethiopia
GERD:	Grand Ethiopian Renaissance Dam
GHG:	Greenhouse gas

GTP I:	Growth and Transformation Plan I
IPAT:	Population Affluence and Technology identity
IPCC:	Intergovernmental Panel on Climate Change
Kg:	Kilo gram
MENA:	Middle East and North Africa
MoFED:	Ministry of Finance and Economic Development
MoWE:	Ministry of Water and Energy
MREC:	Modern Renewable Energy Consumption
MT:	Metric tone
MW:	Mega Watt
NAFTA:	North American Free Trade Agreement
NAMA:	Nationally Appropriate Mitigation Action
NREC:	Non-Renewable Energy consumption
RGDP:	Real Gross Domestic Product
SDG:	Sustainable development goals
UN:	United Nations
UNEP:	United nation environmental program
USA:	United State of America
VAR:	Vector Auto Regressive

VECM:	Vector Error Correction Model
WDI:	World Development Indicators

Chapter One

Introduction

1. 1 Background of the study

Energy plays a vital role in economic and social development. Basically it is one major infrastructure that determines economic growth and development of a country. It is a vital input for economic and social development of any nation because it improves productivity of other factors and living standards. Fast and sustainable energy supply is crucial to economic growth. The high economic growth experienced by developing countries is achievable only with the consumption of a large quantity of energy use (Hailu et al, 2010).

A country with heavy consumption of energy is thought to have a high standard of living. Robust economic growth relies on the development of heavy industries, export and investment in fixed assets etc. which demand large energy consumption. Generally, energy is the life blood of modern economy. Though it is a key factor for economic activities, inefficient and wasteful utilization and distribution of energy causes environmental degradation. (Hailu et al, 2010; Kumar, 2012; Kulionis, 2013; Yangqing, 2012).

This heavy use of energy and other natural resources for economic activities causes environmental degradation because high energy consumption causes high carbon emission which is the main source of rising temperature and climate change.

Climate change is now affecting every country on every continent. It is disrupting national economies, affecting lives and costing people and countries.

Caused by both the earth's natural processes and human activity, over the past hundred years the mean global temperature has increased and the concentration of greenhouse gas in the atmosphere has risen, causing growing incidence of extreme weather conditions such as droughts, floods and hurricanes (Gross,2002).

Given this, the development-environment debate is one of the most important issues of the present time. Particularly the developing economies are expected to undertake their growth process without causing serious environmental damage. But, given the existing technology and science, it is not possible to grow without polluting the environment. That is, given the way the living style of the world's population is constructed, the way production is undertaken and the way goods and services are consumed, pollution and general environmental degradation is expected. Countries meet their ultimate goal of reaching higher level of economic growth and development with different costs, among which is environmental damage or pollution.

World's climate is changing due to both natural process with in itself and human economic activities. Burning of fossil fuel for energy consumption, clearing of forests for agricultural and other purposes and large industrial production are the main activities that lead to increase emission of the anthropogenic greenhouse gas to the atmosphere.

Various alternative means are recommended to reduce the emission of greenhouse gas. Among them energy consumption which is considered as the main responsible sector for the emissions is often criticized for causing global warming and climate change. (Ferhani and Rejeb, 2012; EEA, 2009). So in order to prevent climate change and global warming emission of greenhouse gas must be reduced by relying on efficient and environment friendly alternative energy sources.

Therefore, here is the paradox. Countries have to develop and relieve their citizens from poverty and help them lead decent standard of living. In order to grow and develop they have to produce and consume and this process requires the use of inputs, and energy is the main one. On the other hand, given the present inefficient use of energy, the use of this input leads to degradation of the environment which intern threats the very existence of living in the entire world.

Given this paradox the dilemma between economic growth and environment protection and the coordinated development of energy, environment and the economy and the achievement of sustainable development have become the center of attention (Yangking, 2012).

De-growth, energy efficiency and energy transformation are the three basic options for policy with respect to emission from the energy sources (ADB, 2012). The first option, which will curtain economic growth in their current position, is unthinkable since growth should be a must non-stoppable process given the fact that the world population is growing rapidly. The other two options are the way forward which requires the development of better technology in the sector. International environmental institutions like Intergovernmental Panel on Climate Change (IPCC) and different governments propose the need to shift to alternative environmentally friendly energy sources.

In this context many countries started to shift from traditional polluting energy sources to renewable alternatives such as wind, solar, geothermal and hydropower which are more environmentally friendly (Bozkurt and Yusuf, 2014).

The fact that renewable energy consumption is less harmful to the environment compared to non-renewable energy sources triggers the quest for renewable energy sources and consumption. This source is increasingly gaining share in national energy fuel mixes across both developed and less-developing economies. While developed economies are largely supporting the non-exhaustible energy sources for strengthening security of supply and mitigating climate change impacts through reduced greenhouse gas emissions, renewable energy sources provide favorable option for intensifying rural electrification and improve electricity access in less-developing economies where electricity infrastructure remains mostly low (Nepal,2008).

As stated in the IPCC special report (2012), though the exact contribution of these energy sources to sustainable development has to be evaluated in country specific context, they can offer the opportunity to increase energy access, mitigate climate change and environmental impacts and energy security. It is these and other advantages that initiate different institutions to advocate and countries to redirect their energy policy towards renewable alternatives.

Ethiopia, as one of the most vulnerable and hard-hited nation by the adverse impacts of global warming, has a good reason to participate and contribute to the global efforts at reducing greenhouse gas emission (EEA, 2009).

Energy consumption in Ethiopia is largely dominated by biomass energy sources which accounts for about 88 percent of the total consumption. The remaining balance is met by modern sources of petroleum and electricity. As a least developed country, total energy consumption and associated contribution to the global greenhouse gas emission of the country is among the lowest in the world (MoWE, 2012).

But the country being in the tropical region is with a high potential of modern renewable energy sources including solar, wind, geo thermal and hydropower.

As it is narrated frequently, the country's economy is growing fast and the nation aims to reach middle income status before the year 2025 G.C., and hence the demand for more energy is inevitable. Unless the country is able to develop and utilize its alternative renewable energy sources, continuing with the traditional sources of energy, will result in enormous economic, social and environmental problems.

Cognizant of this fact, the FDRE government has initiated a Climate Resilient Green Economy (CRGE) strategy to protect the country from the adverse effects of climate change and build a green economy that will help realize its ambitions of reaching middle income status before the year 2025 G.C. while keeping greenhouse gas emissions low. Among the four pillars which the initiative identified as the green economy opportunities that can help the nation to reach its ambition are 1) expanding electricity generation from renewable sources of energy for domestic and regional markets and 2) leapfrogging to modern and energy efficient technologies in transport, industrial sectors and buildings. In line with this, the government is developing a lot of alternative energy sources particularly hydropower, wind, geothermal and solar energy.

Therefore studying the emission of greenhouse gas (which CO_2 is the main one) of these different energy sources has a paramount importance for the nation embarking to alternative sources of energy.

1.2 Statement of the problem

The fact that growth and development are the only solution for ever growing human needs and the present way of undertaking this process is environment degrading makes the academia to devote to the study of this interaction.

The growth- environment interaction is the focus of research over the decades based on the environmental Kuznets curve (EKC) hypothesis. EKC is a hypothesized relationship between various indicators of environment degradation and income per capita. It states that the relationship between economic growth and pollution can be represented in an inverted U curve. Pollution increases in an early stage of economic growth and after a certain level of development it will present a downward trend (Stern, 2003; Zerbo, 2015).

This study of the relationship between economy and environment is pioneered by the path breaking works of Grossman and Krueger (1991). Using different environmental indicators and controlling for various factors affecting environment, they tried to assess the relationship between North American Free Trade Agreement (NAFTA)- a trade agreement between USA, Mexico and Canada on the environment (of Mexico particularly). They found out that general economic growth in Mexico is expected to alleviate pollution problems given that the country's per capita GDP reached the level that further growth should generate increased political pressure for the environmental protection and a change in private consumption behavior.

In 1992 Shafik and Bandyopadhyay explored the relationship between economic growth and environmental quality on 149 countries. Their panel regression results suggest that some environmental indicators improve with rising income, others worsen and then improve and others worsen steadily reflecting social choices about environmental quality at different income levels.

Following these pioneer studies many researchers tried to study the economy-environment interaction in different contexts, countries, using different methodologies and hence obtained different results. These studies can be categorized in to two or three lines. The first line of research considers the environmental implications of the growth process via testing the EKC hypothesis. That is representing environment by CO_2 emission, deforestation or other variable, they try to analyze the effect of growth activities in these parameters. Gossman and Krueger (1995), Tekalign (2015) are among the studies in this line.

The second lines of studies are those that try to examine the dynamic link between energy use, economic growth and environmental pollution together in a multivariate framework. These are studies that made energy consumption-environment pollution relationship their main focus. These Includes Magazzino (2014), Zerbo (2015), Ferhani and Rejeb (2012), Cetin and Ecerit (2015), Linh and Lin (2015), Tekalign (2016).

The studies by Magazzino(2014), Zerbo (2015)(for some countries), Kohller(2013) and Cetin and Ecerit (2015) indicate that higher energy consumption significantly and positively affect economic growth and pollution while other studies like Zerbo (for some countries) found no effect or negative effect on both growth and pollution. Others like Tiwari (2012) obtained no effect of energy on growth but negative effect to pollution which has important policy implications for energy development, growth and environmental policies.

The common nature of the above two lines of studies is that there is no consensus on the area, particularly the relationship between energy and environment. This might be due to the difference in the countries per capita GDP level and other methodological differences. That is, in wealthier countries time related effects that reduce environmental impacts overwhelms the scale effect which increases pollution and other degradation. On the other hand the scale effect dominates the time related effects in developing countries (Stern, 2003).

Recently researchers are trying to treat energy in a disaggregated form. Here rather than considering different energy sources with different environmental implications in aggregated form, they try to treat them differently as renewable and non-renewable etc. These kinds of researches are more practical and have better policy implications than the previous studies for planners and various institutions to act accordingly by providing practical and specific recommendations. Among the researches in this line are studies by Yazdi et al (2013), Farhani (2015), Jebli and Yousef (2015), Silva et al (2012),Abolhosseini et al (2014), Kulionis (2013).

The studies by Yazdi et al (2013) for Iran, Ferhani (2015) for 12 MENA countries and Jebli and Youssef (2015) for Tunisia found out that increase in renewable energy consumption lead to a decrease in emission of CO_2 in the respective countries though its share in most of the countries is small. Silva et al (2012) for a sample of four countries, Kulionis (2013) for Denmark and Abolhosseini et al (2014) for EU-15 member states studied the causal relationship between renewable energy, GDP growth and CO_2 emission using a VAR framework and found that renewable energy development and consumption will reduce CO_2 emission in all countries in comparison to no-renewable energy.

Almost all of the above studies that treat energy in disaggregated forms found out that renewable energy is less harmful to the environment than non-renewable energy sources. From these empirical findings it can be inferred that renewable energy sources can be a good environmental friendly alternative source of energy to the traditional sources.

Though these results suggest that renewable energy sources are less harmful to the environmental than non-renewable sources, the exact contribution of renewable sources for emission of greenhouse gas has to be evaluated in each country specific context (CRGE, 2012).

In Ethiopia, to the best of the researcher's knowledge, there is no major study dedicated to analyze the comparative effect of alternative sources of which is very demanding given the fact that the country is investing a lot in a renewable sources especially hydropower, wind, solar and geothermal.

Therefore, current study will fall in this more recent and rare line of studies which treat energy sources in disaggregated form and tries to fill the gap. The study has no intention of checking the validity of EKC hypothesis even though it looks at the relationship between economic process and environmental pollution through checking the effect of different energy sources on the emission of CO_2 in the country.

1.3 Data source and type

The annual time series data covering the period from 1981-2014 for modern renewable energy consumption, biomass energy consumption, non-renewable energy consumption, GDP and CO_2 emission for Ethiopia is collected from World Development Indicators (World Bank data base).

CO_2 emission (measured in metric tons per capita) is the dependent variable and modern renewable energy consumption per capita (MREC), biomass energy consumption per capita (BEC), non-renewable energy consumption per capita (NREC) and GDP per capita are independent variables.

Auto Regressive Distributed Lag (ARDL) methodological framework is used to check the effect of these alternative sources of energy to the country's emission of CO_2.

1.4 Significance of the study

Generally, since the country is at a good economic progress and increasing energy consumption, it is appropriate to have this study which examines the implications of renewable energy sources. Particularly renewable energy sources are gaining more attention in the country's energy and general growth and development policies and strategies and a lot is being invested on it. This fact and absence of previous studies in the country that treats energy sources in disaggregated form motivated the present study which can have high implication to policy.

1.5 Objective of the study

The present study will generally examine the energy – emission relationship in Ethiopia with a particular emphasis on different energy sources.

Specifically the study seeks to check

i- The effect of consumption of modern renewable energy on the emission of CO_2

ii- The effect of consumption of biomass renewable energy on the emission of CO_2

iii- The effect of consumption of non- renewable energy on the emission of CO_2.

iv- The effect of growth in GDP per capita on emission of CO_2 in Ethiopia.

1.6 Organization of the paper

The remaining part of the study is organized as follows. Chapter two contains the existing theoretical and empirical reviews on the study area. Chapter three deals with the country's profile with regard to energy consumption and development, emission of greenhouse gas and institutional and policy efforts in the country towards renewable energy alternatives. Chapter four entirely explains the methodology used to achieve the objective of the study. Chapter five is devoted to the result of the descriptive and econometric study and discussions on the obtained results. The last chapter is all about conclusion and recommendation.

Chapter Two

Review of Theoretical and Empirical Literature

2.1 Review of Theoretical Literature

2.1.1 Introduction

Economic activity, which is part of the natural environment, interacts with the environment in complex and dynamic ways. The environment provides different services to the economic system. These include material and energy resources as inputs, spiritual and educational values, life support services and waste assimilative capacity. The air we breathe, the water we drink, the beauty and diversity we observe, rainfall and soil that affect the productivity of the production process are the critical contribution of the environment to the economic system. In turn the environmental impacts of economic activity can be seen in terms of extraction from or insertion in to the environment. That is economic activity affects the natural environment by the emission of anthropogenic pollutants that degrade the nature and change the global climate (Perman et al., 2003; Grossman and Krueger, 1995).

The size and structure of the economic activity is fundamentally shaped by the environment and the environment in turn is affected by the use of resource and generation of pollution and wastes from the economic system. This emission of wastes and pollutants and degraded environment affect the general system of the environment which manifests the change in the form of changing climate-which is mostly mentioned as the problem of global climate change.

Climate change is now recognized as one of the major threats to human existence. People are experiencing the significant impacts of climate change which is manifesting itself in terms of more extreme weather events, destructive storms, melting glaciers and rising sea level. It is affecting every country and disrupting national economies, affecting lives , costing people and communities dearly today and even more tomorrow (EEA, 2009; UNSDG, 2016). The accumulation of greenhouse gas in the atmosphere in the past century is already influencing today's climate and the trend is likely to become more profound with time (ADB, 2012).

Though natural process itself can lead to the change in the climate system, anthropogenic forces associated with human economic activities is the main driving force behind climate change. Extraction of resource for production, clearing of forests and other resources for energy use and other land use purposes etc. leads to the increase in the accumulation of greenhouse gas.

This accumulation of greenhouse gas in the atmosphere is the main driving force behind the change in the world climate and the main contributors to this accumulation is emission from the developed and emerging large economies. The six largest contributors to the emission of CO_2 - which is the major greenhouse gas in the atmosphere, in 2013, (according to the report by the European commission) are China, USA and European Union, India, Russian Federation, and Japan. On the other hand, the poor with lower adaptive capacity is the most vulnerable to the adverse impacts associated with changing climate. This is because climate change is a global challenge that doesn't respect boundaries. Emissions anywhere affect people everywhere.

The impact of climate change is becoming a ''clear and present danger '' now than ever since it is costing millions of lives. As a result the international community's attention to the cause, effect, and solution to the issue of climate change gets momentum over the last few decades. Given this, the dilemma between economic growth, societal improvement, and environmental protection and the achievement of sustainable development become the center of attention (Yanqing, 2012).

Consequently, sustainable development which represents a paradigm linking economy, society and the environment and aimed at economic and social development integrating with environmental protection become on the center of the discussion (IPCC, 2014; ADB, 2012). Sustainable development is a development that meets the needs of the present generation without compromising the ability of the future generation to meet their own needs. However, it is a general concept and doesn't provide on how to achieve this.

As a result in order to provide a concrete policy frameworks to the broad concept of sustainable development and on how economic development and environmental sustainability can reinforce to each other and create a win-win synergy to achieve the three pillars of sustainable development (economy, society and environment), green growth emerged as an alternative path to the conventional growth path (ADB, 2012).

Green growth as defined by the World Bank 2012 is a growth that is efficient in the use of natural resources, clean in that it minimizes pollution and environmental impacts and resilient in that it accounts for natural hazards. It is an economic progress that fosters environmentally sustainable, low carbon and socially inclusive development (UN, 2010 cited in ADB 2012).

Both green growth and sustainable development are meant to give insights and future policy directions to the two basic challenges of the present world particularly economic world which are societal equity and environmental sustainability. That is any growth process should be inclusive and the benefits of the growth should trickle down to every part of the people to be sustainable. Otherwise the process will end up in to societal and political crisis. On the other hand that growth process must not pose problems to the natural environment which is giving back what it receives in the form of hazards and extreme events and in the long run may threaten the very existence of the human being.

Thus the persistence of environmental degradation and continued inequality in Africa necessitates green growth as path way to achieve sustainable development and create green economy –an economy that result in improved human wellbeing and societal equity while significantly reduce environmental risks and ecological scarcities (UNEP, 2011 cited in ADB, 2012).

Given this different countries started to look for alternative growth path that can be able to mitigate and adapt to climate change and create green economy than following the conventional path.

2.1.2 Energy, Growth and Environment

Energy is a crucial determinant of economic development and general civilization of human being. It is considered as one crucial factor of production or input to all of the goods and services we have today. Since all production involves the transformation of inputs in to products for consumption and all such transformation requires energy, many regarded it as the life blood of modern economy (Kulionis, 2013). It plays an important role in the economic development of a country through enhancing the productivity of other factors of production.

There is a strong connection between the energy sector and the national economy. The development and status of the sector is very much related and dependent on the country's level of socio-economic development. On one hand energy demand, supply and pricing have impact on the socioeconomic development, living standard and overall quality of life of the people (EEA, 2009). Fast, stable, uninterrupted, sustainable and reasonably priced energy supply is vital for economic growth and for maintaining and improving the living standard of all people. Inefficient, and wasteful utilization and underdevelopment of the sector stagnates social and economic development (Hailu, 2010; Kulionis, 2013).

On the other hand higher level of economic development could induce more energy consumption. The nature and status of the economy and changes in the structure, the prevailing macro -economic conditions determine energy demand and supply (EEA, 2009).

The direction of the causal relationship between energy and economic growth though not conclusive is categorized in to four types hypothesis of which has important policy implications.

1- Neutrality hypothesis- there is no causality between energy consumption and economic growth. Given the insignificant share of the sector in total GDP, this hypothesis asserts that increase or decrease in energy consumption have no significant impact on the economic growth. In this case energy conservation policies have no significant impact on the overall economic activity.

2- Conservation hypothesis- there is a unidirectional causality running from GDP to energy. This is the case when a greater economic activity stimulates the use and further production of energy.
3- Growth hypothesis – unidirectional causality running from energy to economic growth. That is energy contributes towards economic growth both directly in the production process and/or indirectly as a complement to labor and capital. The implication is that policies aimed at energy conservation may potentially have a detrimental impact on economic growth.
4- Feedback hypothesis- bi directional causality implying interdependent relationship between GDP and energy consumption where each component may act as a complement to each other. That is, increase in energy consumption results in increase in GDP or vice versa and the other way round, increase or decrease in GDP may result in increase or decrease in energy consumption or vice versa (Kulionis,2013; Magazzinno,2014). The empirical studies, studying this causality doesn't reach consensus yet.

Though energy production and consumption is a crucial determinant of the growth and development of any modern economy, the sector is highly criticized from the environmental grounds. Energy affects environmental quality through deforestation associated with unsustainable biomass energy dependence, emission from burning fossil fuel (petroleum and coal) which are considered as the major source of emission of greenhouse gas to the atmosphere.

As clearly understood, high energy consumption is one of the lines demarcating developed nations from developing countries. It is unquestionable that heavy energy consumption is a must for a fast economic growth. However, fast and rapid economic growth can have negative environmental implications since the current production process relies on inputs that are environment damaging (particularly energy sources).

Studies examining the relationship between economic growth and various indicators of the environment test the validity of the so called Environmental Kuznets Curve (EKC) hypothesis. The EKC concept first emerged in 1992 with a path breaking works of Grossman and Krueger whose studies suggests that the environment impact indicator as an inverted U shaped function of economic growth.

EKC is a hypothesized relationship between various indicators of the environmental degradation and income per capita. In early stages of economic growth, environmental degradation and pollution increases but beyond some level of growth the trend will reverse so that at high income levels economic growth leads to environmental improvement (Stern, 2003). As economic activity expands, emission of pollutants tend to increase since some pollutants are natural bi products of economic activities and the current way of producing and consuming are not environmental friendly (Krueger and Grossman,1991). Energy and power production and consumption, trade, transport, construction, industrial production etc. all which are the backbones of any economy produces large amount of wastes and pollution that can degrade the environment.

This proportional increase in the pollution and other environmental wastes from the pure growth in the scale of the economy and due the in ability of the economy to change in the structure and technology is referred as scale effect (Stern, 2003).

But once the economy reaches certain level of income various factors influence production and consumption behavior and lead to reduction of pollutants and improvement in the environment. First as the scale expands there will exist changes in production system such as changes in input and output mix of production which involves the substitution of less environmentally damaging inputs for more damaging inputs. Second, improvements in the technology involve changes in production efficiency and hence reduce emission. Third, as the society becomes richer it began to care for the environment and hence pressurize both the private and public sectors to consider environmental issues beyond its own protection. Finally, due to the public's demand and other reasons government will formulate environment protective laws and policies and employ appropriate institutions that can establish the conditions for environmental improvement (Stern, 2003; Grossman and Krueger, 1991).

Accordingly, this time related effects of production system, societal awareness and institutional and legal factors are expected to bring improvement in the developed economy's environment.

However, the EKC hypothesis, though seems robust is criticized from may grounds particularly its theoretical inadequacy. First the assumption of exogenously given income seems unrealistic. The damaged environment can have a feedback impact on economic activity in different ways and hence can affect the income level. Second aggregate pollution might not be declining in developed countries as it is being observed that as some wastes like sulfur and nitrous oxide decline, others like CO_2 and solid wastes increase (Stern, 2003).

Third, the strong environmental regulation in the developed counties may lead to the migration of industries with higher pollution to developing countries and hence the decline in developed countries pollution and the increase in the developing countries. Forth the environmental improvement expected from developed nations might also be possible in developing ones and good environment might be possible before the assumed higher income level. This is because there is an informal regulation in developing countries, availability of better information now than ever, trade liberalization which can bring more efficient and environmental friendly production etc. (Stern,2003).

2.1.3 Renewable energy, Economic Growth and the environment

Economic progress inevitably hurts the environment given the current way of producing and consuming goods and services. The damaged environment in turn is affecting economic, social and other aspects of human being. It even endangered the very existence of human creature. On the other hand economic growth and development are not options but a must survival issues particularly for developing countries. Thus alternative growth and development paths must be followed for this dilemma between economy and environment. Therefore an economic progress must be clean in the environmental grounds, in order to benefit the intended population particularly in the long run.

Given the fact that the energy sector is one major sector contributing to the accumulation of greenhouse gas in the atmosphere which is responsible for the global climate change, transforming the sector to alternative sources which are clean and environmental friendly is a burning issue.

De-growth, energy efficiency and energy transformation are the three basic options for policy with respect to emission from the energy sources as presented by the African development report (2012). The first option is unthinkable since growth should be a must non- stoppable process given the fact that the world population is growing rapidly. The other two options are the way forward which requires the development of better technology in the sector. Energy efficiency (increasing output per unit of energy input) is one important process for creating low carbon pathways. It includes improving the efficiency of end use technologies and processes and the system in which they are used in all spheres from household to the industries (ADB, 2012).

International environmental institutions like Intergovernmental Panel for climate change (IPCC) and different governments propose the need to shift to alternative environmental friendly energy sources. In this respect renewable energy can potentially play a crucial role to increase energy supplies and reduce emission.

Finiteness for exporting countries, risk of heavily depending on imports for importing countries and associated health and environmental impacts for the entire world of fossil fuel (coal and oil) energy sources called for the development of alternative renewable energy sources.(Kulionis, 2013). Renewable energy represents the broad category of energy flows occurring in the natural environment that can be captured for use up to their rate of replenishment. They include hydropower, wind and solar energy, tidal and wave energy, ocean and geothermal energy, and biomass energy. Modern renewable energy alternatives, such as hydropower, geothermal, wind and solar are cleaner in their very nature and hence their effects on the environment particularly to the emission of CO_2 is benign. There are still critics in these sources, especially on hydropower from the ecological perspective that it can harm ecosystem during its production.

But the case with the traditional biomass energy is an exception. It can only be considered as renewable and environmental friendly, if only if it is produced in sustainable manner. That is from environmental point of view it can only be acceptable if it gets produced from animal and plant wastes. But if not and is produced by cutting living trees and not reforested then it will have more greenhouse gas emission and even bigger climate change impacts.

Consequently the nature and source of production of biomass energy determines its competitiveness from environmental aspect. If it is prepared in sustainable manner it will have important co benefits to the environment in particular. These include reduction of emission of carbon, methane and sulfur, reducing deforestation and desertification, reducing dependence on imported energy from abroad given its abundance.

In general renewable energy can provide important benefits as compared to fossil fuel energy sources. As presented in IPCCs special report on the renewables, renewable energy can offer a number of benefits (1) social and economic development, (2)energy access and security (3) climate change mitigation and reduction of environmental and health impacts.

1) Economic and social benefits

Development of renewable energy can enhance economic and social development indifferent ways. It can create ''green jobs'' in the production level and but mainly in the service end of the supply chain including in distribution, sales, installation, maintenance etc. It can decouple the energy –growth relationship by serving as a sustainable input to production and consumption in the economy. Renewable energy, which is environmental friendly, can help social development through supporting human health and women in particular who are suffering high from the unhealthy energy sources. Since it is renewable and doesn't reduce the future harvest, it sustains natural capital (ADB, 2012).

It can also improve the efficiency of the economy that is through a modern technological development and thereby reducing energy intensity (the amount of energy needed to produce one more unit of output) (ADB, 2012).

It is also imperative that fast and high economic development can enhance the investment and technological development in the energy sector and improve the efficiency of renewable energy technologies.

But the main challenge with the deployment of renewable energy can be the cost associated with production, installation and distribution which can hamper the other sectors growth process

2) Energy access and security

Access to modern energy system is a crucial component in transforming the economy and makes the poor to improve its living standard. Developed countries achieve their growth and development agenda by exploiting renewable and non - renewable energy.

In this regard renewable energy sources provide opportunities for low or non-electrified rural poor as alternative source of energy for different a purpose which includes cooking and lighting. As the supply and distribution of stable and sustainable energy facilitates growth, interrupted power supply may result in series economic, social and political problems (ADB, 2012).

In addition renewable energy can provide additional alternative to rely on multiple sources of energy than single fossil fuel sources there by reducing risks.

Local renewable energy development can reduce imports and save foreign exchange of a given country and facilitates growth activities in other sectors of the economy by redirecting the funds. Beyond the funds importing (particularly extracting and transporting) of fossil fuel is susceptible to different risks and hence the local development of RE sources can overcome this risk (ADB, 2012).

3) Climate change mitigation and health benefits

Renewable energy can provide important advantages in particular in the reduction of greenhouse gas which is causing the global problem of climate change. This is because greenhouse gas from renewable energy technologies is in general, lower than those associated with fossil fuel energy.

Non-combustion based renewable energy power generations significantly reduce air pollution and lower associated health impacts. This mitigation potential of dangerous anthropogenic pollutants is the main driving force behind the global support of renewable energy.

Lowering the amount of this dangerous gases which have health impact such as particulate matter, nitrous oxide, sulfur di oxide, CO_2 etc. means improving the health of the people and especially the rural women and therefore enhance the productive potential of the economy (ADB, 2012).

2.2 Empirical review

2.2.1 International studies

Following the path breaking works of Grossman and Krueger (1991) who tried to examine the impact of NAFTA on the environment, there emerged extensive studies examining the relationship between economic progress and environmental degradation. These different countries studies which employ different methodology and varying number and type of variables and hence obtain different results can be categorized in to three lines.

The first line of studies that tries to examine the growth-environment interaction there by checking the validity of the EKC hypothesis represents the economic activity by GDP per capita and environment by emission of different pollutants, deforestation etc. Some of these studies simply aim to check the EKC hypothesis, by seeing the relationship between environment impact indicator and the GDP per capita, while others examine the relationship and causality of different variables that can represent the economic activity such GDP per capita, , trade openness, FDI etc. and the environment impact variable. The popular studies by Grossman and Krueger (1991), Shafik and Bandyopadhyay (1992) and Grossman and Krueger (1995) fall in this line.

Using different environmental indicators and controlling for various factors affecting environment, Grossman and Krueger tried to assess the relationship between North American Free Trade Agreement (NAFTA)- a trade agreement between USA ,Mexico and Canada on the environment (of Mexico particularly). They found out that general economic growth in Mexico is expected to alleviate pollution problems given that the country's per capita GDP reached the level that further growth should generate increased political pressure for the environmental protection and a change in private consumption behavior. They also found that NAFTA will increase Mexican specialization in sectors that cause less harm to the environment and hence positive impact for the environment.

In 1992 Shafik and Bandyopadhyay explored the relationship between economic growth and environmental quality on 149 countries. Their panel regression results suggest that some environmental indicators improve with rising income, others worsen and then improve and others worsen steadily which the authors see this relationship as reflecting social choices about environmental quality at different income levels.

Using multiple countries panel data Grossman and Krueger examine the relationship between per capita income and various environmental indicators in 1995. They included urban air pollution, focal contamination of river basins, contamination of river basins by heavy metals and the state of oxygen regime in river basins as environmental impact indicators. Conforming the above two studies they found no evidence of steadily environmental quality deterioration with rising income. Rather, for most indicators, they found that economic growth brings an initial phase of deterioration followed by a subsequent phase of improvement.

The second lines of studies are those that try to examine the dynamic link between energy use, economic growth and environmental pollution together in a multivariate framework. Considering the fact that the energy sector is the main contributing sector for the emission of greenhouse gas in the atmosphere, studies on this line examine the environmental impacts of the sector and the general economic activity. There are multiple studies on this line too, though the results are still inconclusive and call for further study on the topic.

Magazzino (2014), using a three VAR panel technique, analyzes the causal relationship among energy use, economic growth and CO_2 emission for six ASEAN countries. They found out that energy use significantly and positively affect economic growth and hence a more intensive use of per capita energy leads to an increase in economic activity. This confirmed the growth hypothesis and asserts that energy is a limiting factor for growth. While, it is found that, both economic growth and CO_2 didn't significantly affect energy use, the response of CO_2 emission to real per capita GDP is positive and they claim that an increase in aggregate income results in negative environmental effects through CO_2 emission.

Zerbo (2015) obtained mixed results on the relationship between economic growth, energy use, CO_2 emission and foreign trade for 8 sub Saharan African countries of Botswana, Kenya, South Africa, Togo, Gabon Senegal, Cameroon and Ivory Cost. Using ARDL bound testing co integration approach; the study estimates that only in South Africa and Togo that there exists long run relationship between the variables. Energy consumption is found to have positive effect on Botswana, Kenya, South Africa and Togo CO_2 emission level. However the magnitude of the impact depends on the country's level of economic development that in low income countries the impact is higher than the high income countries. Similarly trade openness has a positive significant impact on Kenya's CO_2 emission while it has negative impact on South Africa. Still this shows that the impact of trade depends on the given level of development of the countries. Economic growth on the other leads to an increase in CO_2 emission of all nations except Togo.

In similar panel data analysis, Farhani and Rejeb (2012), investigates the relationship between energy consumption, GDP and CO_2 emission for fifteen

Middle East and North African countries. While they found out that there is long run relationship between GDP, energy consumption and CO_2 emission, in the short run it is only energy consumption that is found to cause GDP growth and CO_2emission.

Another multiple country analysis by Cetin and Ecertin in sub Saharan countries investigates the co integration and dynamic causal relationship between urbanization, energy consumption and CO_2 emission. Employing panel co integration and Granger causality tests, it is found that there exists long run causal relationship between the variables in the countries under consideration. From the causality tests they also found that energy consumption both in the short and long run, and urbanization only in the long run leads to an increase in CO_2 emission. Thus both energy consumption and urbanization are found to cause environmental degradation and are the main determinants of environmental quality in the panel countries.

Applying similar co integration and Granger causality tests, a study by Kohler (2013), examine the relationship between energy consumption, income, foreign trade and CO_2emission in South Africa which is the largest emitter of CO_2 in the continent and also one of the high energy intensive economies of the world. The findings of the study reveal in the long run energy consumption, economic growth and foreign trade granger causes CO_2 emission. And from the impulse response function, it is found that energy use significantly and positively affects CO_2 emission.

On the other hand, confirming the study by Zerbo (2013), an increase in the country's foreign trade level in total GDP leads to a decrease in CO_2 emission.

Another single country study by Tiwari (2012) attempts to study the dynamic relationship between energy consumption, CO_2 emission and Economic growth for India in 2012. Using Granger causality, Impulse response and variance decomposition approaches, the study seeks to see both the static and dynamic relationship between the variables. In the static causality analysis it is found that energy consumption causes CO_2 emission and unlikely it doesn't cause economic growth. Even in the dynamic relationship, energy consumption causes CO_2 emission highly than it causes GDP. From the results the researcher infers that the contribution of energy to GDP is not significant while its contribution to CO_2 emission is larger which calls for energy efficiency and conservation measures.

The third lines of studies are studies that try to examine the environmental implications of the renewable energy sources which are being advocated as one solution to rely on to overcome the adverse impact of traditional and fossil fuel based energy sources. Here rather than considering different energy sources with different environmental implications in aggregated forms, these researches try to treat them differently as renewable and non-renewable and hence will have more practical policy implications. Among the studies in this line, Yazdi et al (2013), Farhani (2015), Jebli and Yousef (2015), Silva et al (2012), Abolhosseini et al (2014), Kulionis (2013).

Yazdi et al try to provide evidence on the impact of GDP, renewable and non-renewable energy consumption and population on the CO_2 emission in Iran. They found out that Population growth and GDP growth has positive impact on CO_2 emission while, though insignificant, increase in the renewable energy share causes a decrease in CO_2emission in Iran.

Farhani on the other hand used panel co-integration techniques and examines the causal relationship between renewable energy consumption, economic growth and CO_2 emissions for a group of twelve MENA countries. Both in the long run and short run renewable energy found to cause CO_2 emission negatively implying that renewable energy can play an important role in reducing CO_2emissions.

Jebli and Yousef uses ARDL bounds and granger causality approaches to investigate the relationship between per capita CO_2emissions, GDP, renewable electricity consumption, non- renewable energy consumption and international trade (import and export) in Tunisia. Renewable energy consumption granger causes CO_2emission in the long run showing that, increasing renewable energy consumption decreases CO_2 emissions. For both models (with imports and exports) non-renewable energy consumption is found to be an important contributor to CO_2 emission. For the model with exports, a 1 percent increase in renewable energy consumption leads to a 0.08 percent decline in emission in the long run. However for the model with imports, the long run impact of renewable energy on emission reduction is weak and statistically insignificant.

Silva et al analyzes the effect of increasing share of renewable energy sources on the electricity generation on GDP and CO_2 emission using a three VAR methodology on a sample of four countries- Denmark, Portugal, Spain and USA. And they found that increasing renewable energy share on total energy decreases both GDP (except USA) and CO_2, but the CO_2 effects are more significant than GDP effects. Thus increasing renewable energy sources share may initially harm economic growth due to their high cost, but contribute to CO_2 emissions reduction and hence governments may need to complement renewable energy development policies with other policies to achieve environmental goals at least cost.(Silva et al, 2012)

Using a cross country panel data model, Abolhosseini et al, investigate the effectiveness of renewable energy sources, technological innovations and market regulations in emission reduction on EU-15 countries. Their estimation results show that there exists a concave formation between Carbon emissions per capita as a dependent variable and GDP per capita and share of renewable energy share in total power generation. That is a decrease in decreasing rate of carbon emissions regarding GDP and renewable energy in the countries. They attributed the decreasing rate to the reduction in the growth rate of renewable energy deployment due to global recession, policy changes and overcapacities in the wind and solar supply chains.

Kulionis test the causal relationship between renewable energy consumption, GDP and CO_2 emissions in Denmark using a multivariate VAR framework. The causality tests indicate the existence of a unidirectional causality coming from renewable energy consumption to CO_2 emission and the impulse response functions reveal that external shocks to renewable energy has a negative impact on the CO_2emission implying that increasing use of renewable energy sources helps to mitigate the CO_2 emissions.

Almost all of the above studies that treat energy in disaggregated forms (renewable- nonrenewable) found out that, though costly, renewable energy is less harmful to the environment than non-renewable energy sources. That is, they emit less greenhouse gas than non- renewable sources, though their share in total energy mix is still lower in almost all countries and hence the estimation is insignificant in some cases. Given the findings of the second line of studies that treat energy in its aggregate form and the above finding from the renewable energy sources we can say something. While it is found that the energy sector in general is the main contributor to the emission of greenhouse gas to the atmosphere, the findings for renewable energy shows that the sector can play a significant role both to the economic growth and environmental protection if further investment and attention is given to the development of the renewable energy sector.

2.2.2 Studies on Ethiopia

For an economy that is highly based on nature and hence significantly affected by the adverse impacts of climate change, studying the environment- economy interaction has a paramount importance. Ethiopia has negligible contribution to the accumulation of greenhouse gases in the atmosphere but is the most vulnerable to the adverse impacts of the changing environment.

There are few studies dedicated to study the environment economy interaction in the country, and very few associated with the energy sector. Studies by Hailu et al (2010), Sime and Wubshet (2015), Tekalign et al (2014) and Tekalign (2015) are among those studies.

Hailu et al, using ARDL bound and granger causality tests, examined the co integration and causal relationship between economic energy, growth and environment in Ethiopia. They found out that there exists co integration and long run relationship between energy consumption and economic growth and there is a unidirectional causality running from energy consumption to economic growth. Though the long run effect of energy on economic growth is found to be insignificant, in the short run a 10 percent increase in energy consumption leads to 1.2 percent growth in the economy showing the significant role of energy to economic progress. The findings have important policy implication. That is, energy conservation policies could significantly affect economic growth in the country and hence policy measures in the relation to energy consumption require proper attention. Their study also examine whether there exists possibility of substituting one source of energy with the other considering economic and environmental impacts. And they found that it is possible to substitute traditional source of fuel wood and imported petroleum, which impose heavy burden on the foreign exchange and environment of the country, with modern electricity particularly from renewable hydro sources.

The other major study by Sime and Wubshet applied the so called environmental impacts are the multiple product of population, Affluence and Technology (IPAT) identity framework and uses VAR model and co integration techniques and VECM, and assess the driving forces of CO_2 emission in Ethiopia. The identity assumes that environmental impacts are the multiplicative product of Population, Affluence and technology. The granger causality tests reveal that there is a unidirectional causality running from all explanatory variables to CO_2emission. GDP per capita and energy intensity are found to significantly and positively affect CO_2emission. The effect of energy intensity is found to be higher confirming the multiplicative effect of one driving force through the other. That is higher economic growth induces more energy consumption and results in more CO_2emission in the country. They claim that this higher effect of energy intensity on CO_2 emission might be due to high investment that demands more energy use, the rapid growth of urbanization and lower energy efficiency.

Tekalign et al investigates the relationship between energy consumption, CO_2emission and economic growth in Ethiopia in the period from 1970/71-2010/11. Unlike the above two findings the long run relationship between energy consumption and CO_2 emission is found to be insignificant showing that the country's contribution to emission from energy polluting fossil fuel sources is very low since the nation's energy consumption is dominated by hydro and biomass sources. The economic growth of the country significantly and positively causes CO_2 emission indicating that economic activity in the country is increasing CO_2 emission which could confirm the EKC hypothesis that economic growth at its early stage can significantly harm the environment. The other explanatory variable considered was urbanization and is found to be significant and positive in causing CO_2 emission in the country.

Another study by Tekalign in 2015 try to test the existence of the EKC hypothesis in the country using the data from 1969 up to 2011 and applying Johannesen co integration procedure. They proved the presence of the EKC hypothesis's relationship between economy and environment in the country. That is environmental degradation first rises in the country and then decline after a while. The author argues that the initial deterioration in the environment is because the agrarian nature of the economy that can heavily depend on nature for the resource and input use and the decline is due to the structural shift of the economy to the services sector which is assumed to be the least depend sector on nature. Addition they give credit to the environmental laws that country being implementing for the improvement in the environment.

Though few, the above studies try to see the economy environment interaction in general and energy, growth and emission relationship in particular, in Ethiopia. But to the best of the researcher's knowledge there is no study dedicated to analyze the energy sector in disaggregated form, particularly the emission of renewable energy and non-renewable energy sources in the country.

Chapter Three

Overview of Energy and Emission in Ethiopia

3.1 Ethiopia's Energy sector overview

Energy development and consumption is one of the signs of level of development and civilization of a given society. In the traditional and uncivilized society where economic activity is primitive and income per capita is very low, energy consumption is dependent on biological sources, crop and animal residues and human effort. In the intermediate stages more processed biofuels, animal power and some commercial fossil fuel and in the advanced world, highly commercial fossil fuel and ultimately electricity will dominate the sector (EEA, 2009).

As a developing nation, Ethiopia's energy consumption is characterized by heavy dependence on traditional energy sources such as biomass energy and very low proportion of modern sources of electric city and petroleum. The biomass energy which is obtained from fuel wood, charcoal, branches, dung cakes and agricultural residues provides about 88 percent of total energy consumed in the country (MoWE, 2012).

At a national level, about 80 percent of households use fire wood, around 12 percent cook with leaves and dung cakes and only 3 percent use kerosene for cooking (MoWE, 2012).

This heavy dependence on biomass energy has serious environmental impacts in addition to the economic and social issues. First, since, the consumption of fuel wood has exceeded its supply and the demand is further estimated to grow in the coming years at faster rate, this dependence will further aggravate deforestation and in the long run will lead to environmental degradation, desertification, increased flooding, and famine. Secondly, domestic cooking with biomass with inefficient and improperly ventilated stoves and kitchens results in high indoor air pollution. Thirdly the burning of wood emits greenhouse gas that will result in change in the climate and further health impacts (EEA, 20019; CRGE, 2012; MoWE, 2012).

Adding to the fuel, the import of petroleum which covers some portion of the remaining balance of energy demand has been creating huge budgetary burden and result chronic foreign currency shortage. Generally speaking the prevailing pattern of the Ethiopia's energy production and consumption is unsustainable.

From the international standards, the problem with the country's energy sector is not only its unsustainability, but also lower per capita consumption. Since it is a well-known fact that high and modern energy consumption is a very basis of higher growth and development and living standards, Ethiopia's low level of socio economic development is attributable to its low development and consumption of energy, among other things (EEA, 2009).

In terms of sectors, household consumption takes around 90 percent of the total energy followed by the transport sector which consumes about 6 percent of the total energy production. The remaining energy is consumed by the industrial, services and agriculture sectors (MoWE, 2012).

Lack of access to adequate, affordable, reliable, and environmentally friendly energy is a severe constraint to the development of the country. That is why, in today's Ethiopia, energy is at the heart of economic, social and environmental issues (EEA, 2009).

3.2 Overview of Ethiopia's Emission Profile

Though the country's energy dependency is unsustainable from many grounds, particularly from environment, from regional and international context, Ethiopia's contribution to the global increase in greenhouse gas emission is negligible. It is around 150mt CO_2eq and 2t CO_2eq per capita emission in 2010 (CRGE, 2012).

As it is clearly presented in the CRGE document, out of the 150 mt CO_2eq in 2010, more than 85 percent of greenhouse gas emissions came from the agricultural and forestry sectors followed by power, transport, industry and buildings, which contributed 3 percent each.

The below figure reveal this fact.

Figure 3.1 Share of greenhouse gas emission by sector in 2010

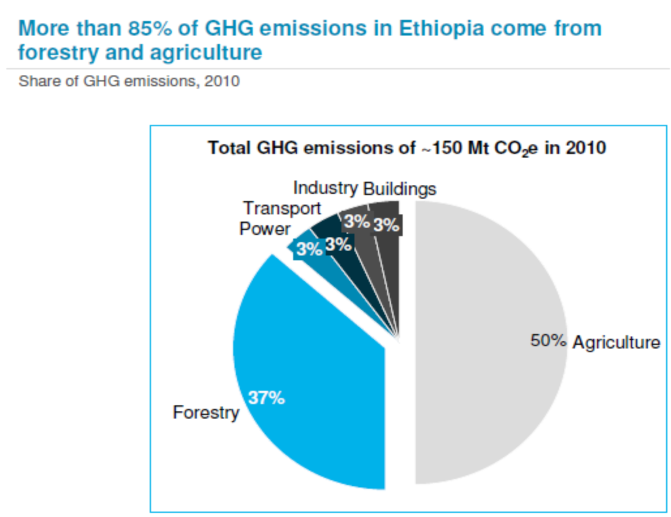


Figure source: CRGE (2012) document.

In agriculture, greenhouse gas emissions are attributable to livestock and crops. Livestock generate greenhouse gases mainly in the form of methane emissions arising from digestion processes and nitrous oxide emissions arising from excretions. Livestock emissions were estimated to amount to 65 Mt CO_2eq in 2010 – more than 40 percent of the total emissions. The cultivation of crops contributes to the concentration of greenhouse gases mainly by requiring the use of fertilizer (about 10 Mt CO_2eq) as well as by emitting NO_2 from crop residues reintroduced into the ground (about 3 Mt CO_2eq)(CRGE, 2012).

In forestry, the impact of human activities is a large source of CO_2 emissions amounting to almost 55 Mt CO_2eq in 2010. Forestry emissions are driven by deforestation for agricultural land (50 percent of all forestry-related emissions) and forest degradation due to fuel wood consumption (46 percent) as well as formal and informal logging (4 percent).(CRGE,2012)

In transport, around 75 percent of the emissions come from road transport, particularly freight and construction vehicles, and to a lesser extent private passenger vehicles. Air transport also contributes a significant share (23 percent of transport- related emissions). Emissions from inland water transport are small (CREGE, 2012).

The electric power sector only accounts for very low emissions as it is largely based on renewable energy, with hydro power accounting for more than 90 percent of total power generation capacity. Current emissions in the energy sector amount to below 5 Mt CO2eq or a share of 3 percent of the country's total emissions. (CRGE, 2012)

Industry accounts for only 3 percent of greenhouse gas emissions. At nearly 2 Mt CO_2eq or 50 percent of the 4 Mt CO_2eq emissions from industry, cement is the single- largest industrial source of emissions, followed by mining (32 percent), and the textile and leather (17 percent) industry. Emissions from steel, other types of engineering, the chemicals industry (incl. fertilizer), pulp and paper industry and food processing together account for only around 2 percent of industrial greenhouse gas emissions. (CRGE, 2012)

Lastly, buildings contribute around 5 Mt CO_2eq or 3 percent to emissions. Main drivers are emissions related to solid and liquid waste (3 Mt of CO_2eq) and the use of private power generators in cities (2 Mt of CO_2eq) (CRGE, 2012).

From the above statistics, it can be inferred that, more than 40mt CO_2eq (around 27 percent) of the total emission are directly or indirectly related to the energy production and consumption. Out of the total 40 mt CO_2eq, about 25 mt CO_2eq (more than 75 percent) are from the biomass energy (fuel wood consumption) followed by modern power generations and modern fuel (petroleum) consumption each accounting for 5 mt CO_2eq.

And according to projections in the document, if economic development and population growth continue in Business As Usual (BAU) scenario, greenhouse gas emission will increase to 400 mt CO2eq in total and to 3 t in per capita term in 2030.

In addition, if the Business As Usual (BAU) scenario prevails, the country would loss more foreign currency to import less environmentally friendly sources and lock into outdated technologies and in the very long run lowers the quality of life, health problem and polluted environment (CRGE, 2012).

On the other hand, Ethiopia being a tropical country and endowed with enormous natural resources is with a good potential of generating energy from modern renewable and environmentally friendly sources. It has an estimated potential of 45000 MW hydroelectric power, 700-1000 MW geothermal energy and more solar, wind and other alternative energies. (Embassy of Japan, 2008).

If the country is able to appropriately utilize these alternative renewable sources, it has the capacity to export energy to the neighboring countries which will become source of foreign currency and additional comparative advantage to the country.

Due to various reasons, the country is not able to sufficiently exploit its abundant and environmentally friendly energy yet. But now it is not a choice rather a must to utilize these sources of energy dictated by the unsustainable nature of the existing energy, ever growing demand associated with high population growth, fast economic growth and urban population and the current suffering from the adverse impacts of degraded environment and climate change etc.

3.3 Institutional and Policy Commitments and Developments

Cognizant of the above facts, the country has been trying to develop some of its modern renewable energy sources so far. In particular the FDRE government gave prior attention to the development of the energy sector and to the exploitation of the renewable energy sources in particular. In its first energy policy, drafted in 1994 during the transitional government, it states that the priority is given to the hydropower development recognizing that water is abundant resource in the country and other renewable sources that their effect in the environment is benign such as geothermal, solar, wind.

Subsequent development plans which the country implemented further elaborate this draft policy and give more attention to the sector and to the renewable sources in particular. For instance, the GTPI (country plan from 2010-2015), underlines the importance of promoting and realizing the country's green development strategy through biofuel development and other renewable energy sources.

The 2012 draft document prepared by the then MoWE and titled as "Scaling up Renewable Energy program – Ethiopia Draft Document" emphasized the urgent need to embark on to the renewable energy development more than ever recognizing the unsustainability of relying on traditional biomass and the price the country is paying in terms of foreign currency loss to fuel import and impact on the environment.

The responsibility of overseeing the implementation of the program will be on the established Environmental Ministerial Council which contains Ministry of Water and Energy (MoWE), Environmental Protection Authority (EPA) and ministry of Finance and Economic Development (MOFED) (MoWE, 2012).

In the same year the country prepared its green economy strategy-the CRGE initiative which is prepared by Environmental Protection Authority and the Ethiopian Development Research Institute under the leadership of the Prime Minister's Office. The document states that following the conventional growth path will result in an increase in greenhouse gas emissions and further climate change impacts and the need to follow green economy path.

Recognizing the facts that the country is moving forward in economic front, high population growth and the ambitious target the nation sets to reach, the conventional growth path that developed countries follow will not serve particularly for the achievement of the three dimensions of sustainability –

economy, society and environment. As a result the document is prepared as a guideline for the country on this track (CRGE, 2012).

It is clearly explained, in the initiative, that, as its aim is to protect the country from the adverse effects of climate change and build the green economy that will help realize its ambition of reaching the middle income status before the year 2025. It looks for various green economy opportunities that will help the nation reach its ambitious targets while keeping greenhouse gas emission low.

As it is explained in the document, in order to harmonize economic growth and environmental protection, the initiative has on three objectives

- Fostering economic development and growth
- Ensuring abatement and avoidance of future emissions, i.e., transition to a green economy
- Improving resilience to climate change.

This green economy plan is based on four pillars.

- Improving crop and livestock production practices for higher food security and farmer income while reducing emissions
- Protecting and re-establishing forests for their economic and ecosystem services, including as carbon stocks
- Expanding electricity generation from renewable sources of energy for domestic and regional markets
- Leapfrogging to modern and energy-efficient technologies in transport, Indus trial sectors, and buildings

In addition to the above moves, the country established different institutional and legal frameworks to control the adverse impacts of economic activities on the environment. Among them is, Nationally Appropriate Mitigation Action

(NAMA) whose objective is to identify immediate priorities for the flow of available international climate finance and seize opportunities presented by low carbon technologies and invest in green industries (MoWE, 2012).

The other is Environmental Impact Assessment Governance System (EIAGS) which is a proclamation adopted by the government with the objective of predicting and determining the possible adverse impact of a proposed and ongoing development activity (MoWE, 2012).

As one can clearly understand from above, the country and the government shows their commitment to follow the green economy path in order to achieve the country's vision of reaching middle income status before 2025. In line with this, currently, the country is developing the energy sector from the renewable and environmentally friendly sources. Particularly the hydro power is given more attention and is being currently exploited in various projects to generate electricity including the Grand Ethiopian Renaissance Dam (GERD) which the nation expects to generate more than 6000 MW of electric city when completed and starts full operation. Biofuel energy is also being targeted to utilize in sustainable and modern manner by developing biodiesel and bio ethanol.

In addition to the hydro power and bio fuel, wind, solar and geothermal energy projects are underway in the country as alternative energy sources to the nation

Chapter Four

Data, Model and Methodology

4.1 Data, variables and model

This study employs annual time series data covering the period from 1981-2014. The period chosen was based on the availability of data for all the variables simultaneously. Particularly for the energy variables the data prior to 1981 and after 2014 are not available and hence the study is restricted to this time period only. The data on the variables are all obtained from World Bank's World Development Indicators (WDI) data base.

The variables included are CO_2emission per capita, real GDP per capita, biomass energy consumption per capita, modern renewable energy consumption per capita and non-renewable energy consumption per capita.

CO_2 emission (measured in metric tons per capita) is an environmental indicator capturing the emission of the gas from energy and other economic activity, particularly from the burning of fossil fuel and manufacturing of cement. It is chosen to represent environment from many grounds. First it is the main greenhouse gas in the atmosphere accounting for about 75 percent of the total emission. Second it is the main gas emitted from energy related activities. Third it is being targeted to be reduced in order to improve the environment. And it is also the most commonly used indicator in other previous studies. For example Magazzino 2014, Zerbo, 2015, Ferhani and Rejeb, 2012, Tekalign, et al, 2014, Yazdi et al, 2013, Jebli and Youssef, 2013, Silva et al 2012 used CO_2 emission to represent environment.

GDP per capita (in current US dollar) representing the general economic activity and improvement in the economy is the most widely used indicator of growth.

Energy consumption is disaggregated in to three, one as modern renewable energy, biomass energy consumption and the other non-renewable energy in order to analyze the separate environmental implications in general and emission of CO_2 in particular of these alternative energy sources. Since renewable energy source is at the fore front of the discussion and set as a policy direction to improve the environment by relying the energy sector in to it and its comparative effect on the environment should be studied in each country context, the present study aims to investigate the effect of this sector to the emission of CO_2 in comparison to other non-renewable and other sources of energy in Ethiopia.

Biomass energy (measured as kg of oil equivalent per capita) includes combustible biomass energy (comprising solid biomass, liquid biomass, and biogas) and waste, (including industrial waste, and municipal waste). And the modern renewable energy (measured in Kg of oil equivalent per capita) includes relatively clean energy that produces less carbon dioxide when generated. It includes hydropower, geothermal, wind and solar power, among others. While non-renewable energy (measured as kg of oil equivalent per capita) basically comprises fossil fuel (petroleum) energy which is the main non-renewable source which the country rely on by importing.

Biomass energy is as good to the environment as its dependence on inputs for production. That is, it is good if it is produced from animal and crop wastes and hence it may have both economic, environmental and health benefits. But if not and is produced by cutting living trees through deforestation, then it might lead to more emission and further climate impacts. Even its renewable nature depends whether sufficient amount of trees are planted or not. As a result, the researcher gets it important to treat biomass energy independently without including it into either renewable or non-renewable energy categories.

All the variables are in per capita terms to account for the ever growing population.

Due to the fact that it is very recently that researches consider energy in disaggregated forms such as renewable and non-renewable, there is little account about the theoretical relationship of these energy forms and emission. But in most of these recent studies energy sector is the main variable in studying about emission of gases and climate change in general. As a result the present study tries to explicitly and separately treat the different energy forms as determining factors of emission in Ethiopia. In addition GDP is among the variables that show significant growth over the study period and can result in higher emission and as a result it is also assumed to influence emission of CO_2.

Consequently the following general equation representing the relationship between the variables is proposed.

$$CO_2 = f(Y, BEC, MREC, NREC) \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{eq4.1}$$

Where CO_2 represents Carbon di oxide emission per capita, Y represents GDP per capita, BREC is biomass energy consumption per capita , MREC is modern renewable energy consumption per capita and NREC is non-renewable energy consumption per capita.

4.2 Econometric methodology

Various approaches have been applied to examine the long run dynamic relationship between the variables of interest so far. These include Engle and Granger and Johansen approaches. The present study uses Autoregressive Distributive Lag (ARDL) approach to test the presence of long run co integrating relationship between CO_2 emissions per capita, GDP per capita, biomass energy consumption per capita , modern renewable energy consumption per capita and non-renewable energy consumption per capita. ARDL approach first developed by Pesaran and shin 1997 and later extended by Pesaran et al (2001) is preferred to other approaches due to the following advantages as stated in Halicioglu (2009), Narayan (2005), Pesaran and Shin (2001);

- It is developed in the field of Auto Regressive Distributive Lags Models (dynamic models).
- Avoids the inability to test the hypothesis on the estimated coefficients in the long run.
- Both long run and short run parameters are estimated simultaneously
- It is more efficient in small sample size
- It takes sufficient number of lags to capture the data generating process in a dynamic framework.
- Is relived of establishing the order of integration among the variables and of pretesting for unit roots since it could be applied regardless of whether the variables are I(0), I(1), or fractionally integrated.
- Involves just a single equation setup, making it simple to implement and interpret.

In order to estimate the relationship between the variables using ARDL framework, the following procedure could be followed.

- ✓ First- it is important to check the stationarity of the variables and making sure that none of the variables are I (2), as such data will invalidate the methodology.
- ✓ Second –determine the optimal lag structure of the model
- ✓ Third –undertake stability and diagnostic tests for the model
- ✓ Fourth- perform bound test to check the existence of co integrating relationship between the variables
- ✓ Five -estimate the long run and short run models

4.2.1 Stationary or unit root test

A stochastic process is said to be stationary if its mean, variance and auto covariance remains the same no matter at what point we measure them, i. e they are time invariant and will have constant movement. If so, then, the estimators obtained from estimation will be consistent and the results can be generalized for the purpose of policy analysis and forecasting. However the time series variable can fail to be stationary may be due to the series have persistent long run movements (trends) or it can be unstable overtime (i.e.it can have breaks), etc.

If we consider different unrelated variables which are non-stationary (move up or down or have breaks etc.) and perform the normal regression, we may find significant positive or negative relationship depending on their direction of movement while they are unrelated. This is what is called spurious regression. In this case it can only be possible to study about the behavior of the variable at point in time but not possible to infer the results to other periods too. That is, the standard regression results (which require the variables to be stationary) can generate spurious results and lead to incorrect conclusion about the relationship between the variables.

In practical world most of the macroeconomic variables are non-stationary and hence proper care should be taken to the issue of stationary of the variables in order to avoid the problem of spurious regression before going to estimation.

Various techniques have been applied to test the existence of unit root (non-stationarity) of the variables. The present study uses Augmented Dicky-Fuller test (ADF test)-which is the most applicable test.

The three possible forms of the ADF test for a time series variable Y_t are given as

$$\Delta Y_t = \delta Y_{t-1} + \sum_{i=1}^{p} \beta i \, \Delta Y_{t-i} + u_t \quad \text{………………………eq4.2}$$

$$\Delta Y_t = \alpha + \delta Y_{t-1} + \sum_{i=1}^{p} \beta i \, \Delta Y_{t-i} + u_t \quad \text{……………………eq4.3}$$

$$\Delta Y_t = \alpha + \gamma t + \delta Y_{t-1} + \sum_{i=1}^{p} \beta i \, \Delta Y_{t-i} + u_t \quad \text{…………..eq4.4}$$

Where; α is intercept, γ is coefficient of time trend, t is time trend variable, u_t is random white noise process, Δ is the first difference operator and δ and β are parameters to be estimated.

Equation 4.2 is without intercept and non-stochastic time trend. Equation 4.3 with the intercept term only and equation 4.4 is with both the intercept and time trend. This is to capture the difference in time series whether they start from the origin (evolve around the zero or around some constant) and have some kind of visible time trend (Kulionis, 2013).

In order to test the stationarity of the variables, the hypothesis

For equation 4.2 is

$H_o: \delta = 0$ or Non stationary (the series contains a unit root)

Against

$H_1: \delta < 0$ or the series is stationary

Forequation4.3is

$H_o: \delta = 0$ and $\alpha \neq 0$ $y_t$is Non stationary (has unit root)

Against

$H_1: \delta < 0$ and $\alpha \neq 0, y_t$ is stationary

Forequation4.4is

$H_o: \delta = 0$ and $\gamma \neq 0$ $y_t$is Non stationary (has unit root)

Against

$H_1: \delta < 0$ and $\gamma \neq 0, y_t$ is trend stationary

to be tasted.

Using critical values for each of the above models and comparing it with ADF statistical values we can reject or accept the null hypothesis. That is if the t-statistics is greater than the critical values (in absolute value) we reject the null hypothesis (i.e. the series is stationary) and accept the null hypothesis of having unit root if t-statistics is less than the critical values (in absolute values).

4.2.2 Co integration and Error correction Model

When two stochastic trends are really related then it is expected that they would be very similar to each other and will move together. Then a combination of them will be stationary and then the series are said to be co integrated. That is, if there really is a genuine long run relationship between two variables, even though they are trend stationary, then their linear combination (a common trend that links them together) will be a stationary series.

Particularly when the non-stationary series are integrated of different orders then it is advisable to apply "Bounds testing approach for co integration with ARDL framework" in order to estimate the co integrating relationship between the variables.

In a time series analysis a time lagged values of the explanatory variables and lagged values of the dependent variable may influence the dependent variable and hence these lagged values of the variables should be included in the regression. This consideration motivates ARDL model specification and appropriate selection of the lag length to be included.

Accordingly, for the present study, the following ARDL model is specified to check the existence of long run co integrating relationship between the variables.

$$\Delta CO_{2t} = \beta_0 + \beta_1 Y_{t-1} + \beta_2 BEC_{t-1} + \beta_3 MREC_{t-1} + \beta_4 NREC_{t-1} + \sum_{i=1}^{p} \Delta\theta_1 Y_{t-i} + \sum_{i=1}^{p} \Delta\theta_2 BEC_{t-i} + \sum_{i=1}^{p} \Delta\theta_3 MREC_{t-i} + \sum_{i=1}^{p} \Delta\theta_4 NREC_{t-i} + u_i \text{…eq4.5}$$

Where $\beta_1, \dots, \beta_4$ are coefficients that measure long run relationship.

$\theta_1, \dots, \theta_4$ Measure the short run relationship. (detail derivation of the ARDL model can be found in the appendices section, appendix 1).

Then the hypothesis will be;

$$H_0: \beta_1 = \cdots = \beta_4 = 0$$

$$H_1: \beta_1 = \cdots = \beta_4 \neq 0$$

The co integration test (bound test) is based on F-statistics. That is, if the f-statistics is greater than the upper bound critical values, the null hypothesis will be rejected and hence there exists co integrating relationship among the variables and if the f-statistics is lower than the lower bound values the null hypothesis of no co integration is accepted. But if the F-statistics lies in between the upper and lower bounds, then the test will be inconclusive and hence further test is required.

4.2.3 Short run and long run models

Once it is found that there exists co integrating relationship between the variables the next step will be estimating the short run and long run models. For the present study the following long run model is selected or specified.

$$CO_{2t} = \beta_0 + \beta_1 Y_{t-1} + \beta_2 BEC_{t-1} + \beta_3 MREC_{t-1} + \beta_4 NREC_{t-1} \ldots eq4.6$$

Where; $\beta_1, \ldots, \beta_4$ are the coefficients representing the long run relationship between the variables.

And for the short run, ECM, which is the error correction reparametrization of the long run model, shows the dynamics of the model with the long run equilibrium.

$$\Delta CO_{2t} = \sum_{i=1}^{p} \Delta\theta_{1i} Y_{t-i} + \sum_{i=1}^{p} \Delta\theta_{2i} BEC_{t-i} + \sum_{i=1}^{p} \Delta\theta_{3i} MREC_{t-i} + \sum_{i=1}^{p} \Delta\theta_{4i} NREC_{t-i} + u_i \ldots\ldots\text{eq4.7}$$

Where; $\theta_{1i}, \ldots, \theta_{4i}$ are the coefficients representing the short run dynamics of the model.

4.2.4 Diagnostic and stability tests

Diagnostic and stability tests re tests to check the soundness of (standard property) of the model. These tests are undertaken to make sure that the model and estimated coefficients are reliable and can be inferred or not. These include tests for normality, model specification tests, tests for the presence of serial correlation and stability of the model. As explained in Gujarati (2003) the above concepts are explained very briefly below.

Normality of the error term is the other test for the distribution of the error term whether they are normal or not for all observations and hence the influence of the terms included in the error term are small and at best random. The test for the serial correlation is testing whether the different lagged values of the error term are correlated or not.

The other important test is the test for the specification of the model. That is whether there is no specification bias or error in the model used.it checks whether important variables are excluded or not, unrelated variable is included or not, the functional form of the model and assumptions made.

Therefore our model will be checked whether it passes the above tests or not using appropriate techniques for each.

Chapter Five

Empirical Results and Discussion

5.1 Descriptive Analysis

Table 5.1 shows the descriptive statistics of all the variables consisting of 34 observations of each. The standard error of the variables indicates that real GDP per capita has the highest value and CO_2emission per capita has the lowest. That is, real GDP per capita is more scattered (from its minimum value 111.5312 to its maximum value 573.5660) than others and CO_2 per capita is less scattered and its value is concentrated around its mean (having minimum value of 0.039922 and maximum value of 0.121294) than other variables. From the energy variables, it is non-renewable energy consumption per capita that shows significant variation between its minimum value of 10.57077 and maximum value of 30.49320 followed by modern renewable energy consumption per capita which also has risen in the study period from its minimum level of 1.208035 to 8.671896. Biomass energy consumption per capita does not show significant variation except its declining trend in the latter periods. The mean values of each of the variables are found to be positive.

Table5.1 descriptive analysis results

Variables	***Mean***	***Std.dev.***	***Min***	***Max***	***Obs***
CO2	***0.063437***	***0.018827***	***0.039922***	***0.121294***	***34***
BEC	***458.6940***	***0.720075***	***458.3699***	***460.6734***	***34***
MREC	***2.922080***	***1.933886***	***1.208035***	***8.671896***	***34***
NREC	***18.24177***	***4.797336***	***10.57077***	***30.49320***	***34***
Y	***231.7832***	***115.9196***	***111.5312***	***573.5660***	***34***

5.2 Unit Root Test Results

As stated in the methodological part, the first thing to do in time series analysis is to check the stationarity of variables before going to estimation. This could help us avoid the problem of spurious regression and inappropriate estimation and inference.

Accordingly, a unit root test is carried out using Augmented Dicky-Fuller (ADF) test in order to test the order of integration of the variables (i.e. whether the variables are stationary at level, at their first difference or etc.). As per the stated equations in the methodology, the test is carried out for all the three cases (without intercept and trend, with only intercept and with both trend and intercept).And hence the ADF test results are presented below in tabular form.

Table: 5.2 ADF Unit Root Test result

Variables	*ADF t-statistic at level I(0)*			*ADF t-statistic at level I(1)*			
	Without T&I	*With INT*	*With T& I*	*Without T&I*	*With INTERCEPT*	*With T&I*	*Order of Integration*
CO_2	**2.221169**	**1.636682**	**-0.210291**	*-4.615657**	*-5.213015**	*-5.574131**	*I(1)*
Y	**1.483972**	**0.894192**	**1.119685**	*-3.102723**	*-3.336365***	*-3.678445***	*I(1)*
BEC	**0.998176**	**-0.878693**	**-0.922326**	*-2.722716**	*-2.915042****	*-3.498774****	*I(1)*
MREC	*2.254797*	*5.133849*	*2.291821*	*-1.844920****	*-5.091864****	*-3.331539****	*I(1)*
NREC	**1.639993**	**0.514614**	**-1.935592**	*-4.963553**	*-5.324555**	*-3.209583***	*I(1)*

Source- E-views 9.1 output. And note that *, **, *** represent the level of statistical significance level at 1%, 5% and 10% respectively.

Where; CO_2 is carbon dioxide emission per capita, Y is real GDP per capita and BEC, MREC and NREC are biomass energy consumption, modern renewable energy consumption and non-renewable energy consumption(in K_t of oil equivalent per capita) respectively.

The decision rule is that if the ADF t-statistics is greater than the critical values (in absolute value) we reject the null hypothesis (i.e. the series is stationary) and accept the null hypothesis of having unit root if t-statistics is less than the critical values (in absolute values).

Accordingly per capita $CO_2$is found to be stationary at its first difference in all the cases of without intercept and trend, with intercept alone and with both intercept and trend (at 1 percent level of significance). Real GDP per capita is stationary at the first difference without trend and intercept at 1percent level of significance and also stationary at its first difference with the remaining two cases at 5 percent level of significance.

Biomass energy consumption per capita is stationary when converted it to the first difference at 1 percent level of significance without trend and intercept and stationary at 10 percent level of significance with the remaining cases. The first difference modern renewable energy consumption per capita is stationary at 10 percent level of significance in all of the three cases. Non-renewable energy consumption per capita is stationary when converted to its first difference at 1 percent without trend and intercept and with intercept alone and stationary at 5 percent with both trend and intercept.

According to the above results, the variables are integrated of the same order and none of the variables are integrated of order two, hence making ARDL model to be the appropriate model to run the regression.

5.3 Test Result for Co integration- bound test approach

Once the stationarity of variables is checked and found that ARDL model is appropriate model then the next step will be diagnosing the presence of long run co integrating relationship between the variables under consideration.

In ARDL approach the first task is selecting the optimum number of lags to be included in the model which requires balancing the benefits of including more lags against the cost of additional uncertainty and error in estimation and forecasting.

Here in our case Akaike information criteria (AIC) is used to select the optimum lag length. AIC is a widely used criteria and also suggested by Pesaran and Shin (2001) particularly for small sample size. Maximum of two lag length is selected based on the suggestion by Pesaran and shin who recommend maximum of two lags for an annual data.

And the Eviews result show that the automatically selected lag model is ARDL (1, 0, 2, 0, 2) and is confirmed by the AIC that the selected model have the minimum Akaike value than the rest 20 possible models.

Then the next task will be checking the presence of long run co integrating relationship among the variables. As stated in chapter three, this is carried out using F-statistics (bound test), that is by comparing the calculated F statistics with the critical values; we can accept or reject the null hypothesis of no co integration. That is, is the F-statistics is greater than the upper bounds of the critical values, then we can reject the null hypothesis and hence there exists long run co integrating relationship among the variables of interest and if it is less than the lower bounds of critical values we can accept the null hypothesis. For the present particular case the estimated bound test result is presented below

Table 5.3 bound test result

Model with Unrestricted Intercept & no trend	***At 1% level***		***At 5 % level***		***At 10% level***	
	Lower bound I(0)	***Upper bound I(1)***	***Lower bound I(0)***	***Upper bound I(1)***	***Lower bound I(0)***	***Upper bound I(1)***
Critical values for K=4	***3.74***	***2.86***	***2.45***	***5.06***	***4.01***	***3.52***
F-statistics	***8.103671***					

As shown in above table, the value of the F-statistic (8.103671) is greater than the upper bounds at all levels of significance. Hence, it can be concluded that there is a co-integrating relationship among the dependent variables (CO_2) and the independent variables (RGDP, BEC, and MREC NREC).

5.4 Diagnostic and stability test results

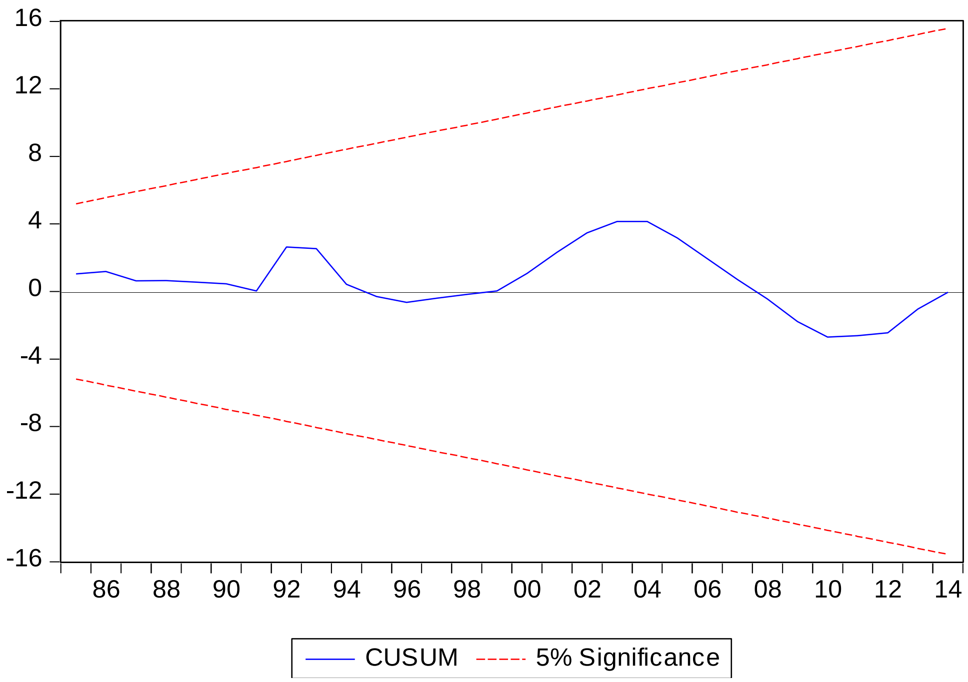
Diagnostic and stability tests are tests to check the standard property or soundness of the model. In the present study tests for normality, testing for the functional form (model specification), stability of the mode and tests for the presence of serial correlation are undertaken and the under listed results are obtained.

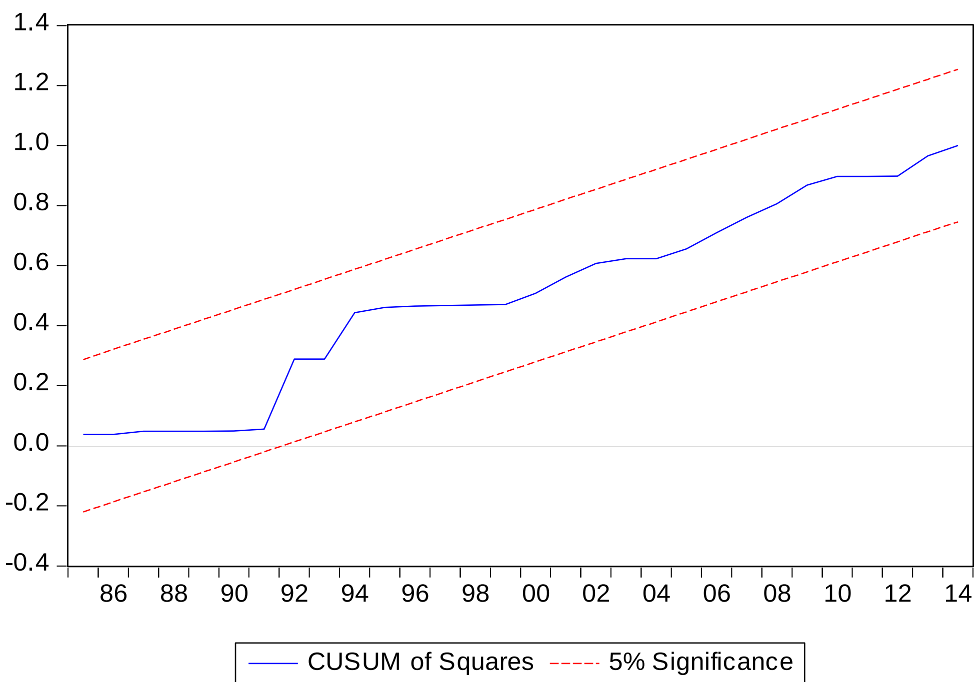
- Functional form test   result using Ramsey RESET Test show that the P-value is 0.0519 which is more than 5 percent and hence the null hypothesis can't be rejected and hence the model did not have omitted variable bias and the is well constructed.
- Jaque-Berra normality test is used to test whether the residuals are normally distributed or not. And the result shows that the P-value is 0.154283 (around 15 percent) which is more than 5 percent, meaning that we can't reject null hypothesis which states that the residuals are normally distributed.
- The Breusch Pagan and Godfrey LM test result show that the p-value is 0.0508(which is above 5 percent) and hence the null hypothesis of no serial correlation is accepted.
- The stability of long –run estimates is tested using cumulative sum of recursive residuals (CUMSUM) and cumulative sum of squares recursive residuals (CUMSUMSQ) tests which are recommended by (Pesaran and Shin, 1999, 2001). Since these kinds of stability tests can be graphed, one can easily identify not only their significance but also the point at which stability (structural break) possibly occurred.

The graph plots both the cumulative sum and the 5% critical lines. And, if the cumulative sum remains inside between the two critical lines or bounds back after it is out of the boundary lines, the null hypothesis of correct specification of the model cannot be rejected. But, if the cum sum goes outside (never returns back) between the two critical bounds there exists series parameter instability problem.

The result graphs from the E-views test are presented below

Figure 5.2 and 5.3 CUSUM and CUSUMSq of recursive residuals





CUMSUM and CUMSUMSQ graphs stay within the limit, and hence confirm that the equation is correctly specified and the model is stable. From these results we can say that there is no structural instability in the model during the sample period. Therefore we can conclude that long and short run estimates are quite stable and there is no any structural break showing the results of the estimated model are reliable and efficient.

Generally the above diagnostic and stability test results indicate that there is no major problem with our model and hence further estimation can be undertaken and the results can be inferred.

5.5 Long Run Model Estimation result

Then the selected model (ARDL (1, 0, 2, 0, 2)) is used to estimate and the following long run coefficient estimates are obtained.

Table 5.4 Long Run Model Estimation Results

Regressors	***Coefficents***	***Std. Error***	***t-stat***	***Prob***
Y	***0.000037****	***0.000020***	***1.899676***	***0.0707***
BEC	***0.021518***	***0.010170***	***2.115887***	***0.0459***
MREC	***-0.005954***	***0.003688***	***-1.614622***	***0.1206***
NREC	***0.004537****	***0.000879***	***5.159870***	***0.0000***
C	***-9.873606****	***4.662019***	***-2.117882***	***0.0457***

The estimated long run equation and the results of the coefficients with their t-ratio can be displayed as

CO_2=-9.8736+ 0.0000*Y+ 0.0215*BEC+ 0.0060*MREC+0.0045*NREC

(1.899676) (2.115887) (-1.614622) (5.159870)

In the long run, non -renewable energy consumption per capita is found to be statistically highly significant. That is it, in line with what the theory says and to the researchers expectation, non-renewable energy consumption affects CO_2emission per capita positively and significantly. For 1 kg of oil equivalent increase in the consumption of non-renewable energy consumption per capita, CO_2 per capita will increase by 0.0045 metric tons.

The result is also in line with other previous studies by Jebli and Youssef (2015) who found significant positive relationship between non-renewable energy and CO_2 emission for both models (with import and with export) in the long run for Tunisia. But the present finding is in contrast to what Yazdi et al (2013) found for Iran who employ ARDL methodology like the present study but found that non-renewable energy consumption enables the country to reduce CO_2 per capita in the long run.

But the finding is in harmony with what the international and domestic institutions and government claim that non-renewable energy (fossil fuel) consumption results in high carbon emission. For instance, IPCC in its special report in 2014 and African Development Bank in its 2012 report call for urgent need to shift to renewable energy alternatives, acknowledging the fact that the current reliance on fossil fuel and other non-renewable energy sources poses serious environmental threat particularly by emitting dangerous anthropogenic greenhouse gases.

In Ethiopia, Ethiopian Economic Association, on its (2009) special report on energy sector, shares similar position with the international institutions that fossil fuel (petroleum and coal) is the major source of emission of CO_2 and nitrogen oxides to the atmosphere.

Statistically, the imported petroleum is mainly used for household consumption, transport sector, industry and buildings that are considered to be major contributing sectors to the emission of greenhouse gas in the country. For example the transport sector alone which consumes the lion share of the fuel in the country accounts for about 3 percent of the total emission of the country.

Biomass energy consumption is also highly significant in affecting CO_2 emission in Ethiopia. The direction of relationship is positive showing that the increase in consumption of biomass energy will result emission of more CO_2. Figuratively, CO_2 emission will increase by 0.0215 for a unit increase in biomass energy consumption which shows that biomass energy has a devastating impact on CO_2 emission in Ethiopia under the study period.

Previous studies that treats biomass energy as a class of renewable energy sources found insignificant relationship between renewable energy and CO_2 emission and the researcher of the present study suspects that the reason behind might be the inclusion of biomass energy. That is the favorable positive impact of modern renewable energy sources to the environment is overwhelmed by the unsustainable biomass energy included in the group. The studies include Yazdi et al (2013) who included wood as renewable and Jebli and Youssef (2015) who included biomass energy as renewable and obtained insignificant effect in model with imports.

Consequently the present trial of considering biomass energy solely from renewable and non-renewable energy sectors seems fruitful. Here it is obtained that biomass significantly and positively affects emission of CO_2 in Ethiopia. As previously explained well in other parts of the study, the country biomass energy consumption is unsustainable. As reported earlier by the then MoWE and also confirmed by the EEA report, access to biomass fuel wood run short of the demand due to the overall forest stock shrinking and biomass energy is being harvested in excess of sustainable yield in the country which will have serious economic, social and environmental repercussions. The result of which will be increasing greenhouse gas emission where CO_2 will be the main one as also confirmed by the present study.

For the growth variable (real GDP per capita) the result is also as expected. Real GDP per capita have positive relationship with CO_2 emission and also is significant at 10 percent level of significance. Figuratively CO_2 rise by 0.000037 units for one unit increase in real GDP per capita. This result is also identical to what similar studies by Sime and Wubshet and Tekalign found for Ethiopia. Both studies found that GDP growth positively and significantly affect CO_2emission in the country. This is basically the increase in energy consumption associated with increased economic activity. The fast rate of urbanization in the country during the study period following the rise in total population, increasing employment opportunities in the urban centers might also lead to more emission. The expansion of industries in the country also which demands more inputs and the production process also might lead to emission.

Regarding the rural Ethiopia, the fast growing population and other factors lead to more economic activity and hence the demand for more agricultural land and other inputs and unsustainable use of natural resources will result more emission. In addition, the process of production also leads to emission of more CO_2. Generally, the economic activity in the country, particularly the last decade of fast economic growth, results in rise in emission of the gas.

5.6 Short Run Error Correction Model Estimation Results

The results of the short run ECM, which show the dynamics of the model towards the long run equilibrium presented in this section. The coefficient of the error correction term should be negative and significant for the model to be valid. That is, it shows that the short run disequilibrium dies out with time and the model will converge to its long run equilibrium. The result of the short run model estimation is presented in the table 5.5 below.

In the short run, Y, MREC and NREC and its one period lagged value, are significant in affecting CO_2 emission in Ethiopia in the study period. Real GDP per capita as in the long run affects CO_2 emission significantly and the sign shows that for a unit increase in real GDP in the study period CO_2emission increase by 0.000023 units. This result is also obtained in other country studies too. For example, Jebli and Youssef (2015) found positive relationship between GDP and CO_2 emission in the short run for Tunisia.

Table 5.5 Short run model estimation result

Regressors	*Coefficents*	*St Error*	*t-stat*	*prob*
D(Y)	***0.000023****	***0.000013***	***1.730711***	***0.0975***
D(BEC)	***-004177***	***0.008927***	***-0.467945***	***0.6444***
D(BEC(-1))	***-0.015281***	***0.010995***	***-1.389850***	***0.1785***
D(MREC)	***-0.003702****	***0.002078***	***-1.781432***	***0.0887***
D(NREC)	***0.002071**	***0.000422***	***4.908296***	***0.0001***
D(NREC(-1))	***-0.001712**	***0.000463***	***0-3.701187***	***0.0012***
Coint Eq (-1)	***-0.621734**	***0.120170***	***-5.173803***	***0.0000***
R squared 0.977791 ***Adj R squared 0.968706*** ***Log likelihood 143.1675*** ***Prob (F-statistics) 0.000000***				

Abolhosseni et al(2014), in thier panel study for EU-15 member countries (which are even developed countries) found significant positive relationship for the two variables and in Kulionis (2013) study it is found that after a very small shock to GDP in Denmark, CO_2emission is increase. Yazdi et al (2013) also obtained GDP positively and significantly and causes CO_2in Iran.

In short run, all of the energy consumption variables (MREC, NREC and BEC) are found to decrease emission of CO_2 in the country, though the coefficient of biomass energy consumption is insignificant. This may be due to the fact that the effect of unsustainable biomass energy consumption might not be seen or reflected in the short run. That is, the effect of deforestation and desertification is a long run issue.

But the rest two, modern renewable and non-renewable energy consumptions affect emission of CO_2 negatively. The outcome for modern renewable energy is in line with long run case but the result for non-renewable is unexpected. But still the result is similar with the findings of Yazdi et al (2013) who obtained negative effect of non-renewable energy consumption in the short run for Iran.

Modern Renewable energy consumption is found to negatively and significantly affect CO_2 emission in short run which has important policy implication. That is, if proper attention is given and further developments are implemented on the sector and its share in total energy mix is raised, then it will play a good CO_2 emission reduction role in the country.

The error correction coefficient Coint Eq (-1) has negative sign and is statistically significant. The coefficient estimated is -0.621734 which shows that the short run shocks will die out at 62 percent speed of adjustment and the model converges to its long run equilibrium correcting the error and hence the variables have long run co integrating relationship.

Regarding the models' goodness of fit, as shown in the above table, the regression result imply, that dependent variable is highly explained by the explanatory variables incorporated in the model. The adjusted R-squared reveals that 96 percent of the short-run variation in CO_2 emission per capita is explained by the explanatory variables This is mainly because, CO_2 is basically emitted from the energy sector. In addition, the growth variable (GDP) is an important variable encompassing all other factor affecting emission of the gas in the country.

Chapter Six

Conclusion and Implication

6.1 Conclusion

The growing concern regarding the emission of greenhouse gas from the energy sector and the resulting global warming have brought renewable energy to the forefront of the discussion and energy choice. It is believed that modern renewable energy is cleaner and sustainable than non- renewable and other traditional energies and hence can provide preferable alternative to the energy sector as a solution to the environmental problems emanating from the sector.

Ethiopia, though highly dependent on traditional biomass and imported petroleum, is developing its modern renewable energy sector particularly hydropower, to meet its ever-growing energy needs and as a means to transform its energy sector to sustainable and environmentally friendly sources.

Given these facts, the present study attempted to investigate the effect of different energy sources which comprises the country's energy sector (biomass, modern renewable and non- renewable energies) to the emission of CO_2 which is the main greenhouse gas emitted from the energy sector in the country. In addition, general economic performance (represented by real GDP per capita) is analyzed as explanatory variable to the variation of the gas in the country.

Using annual time series data from the period 1981 to 2014 collected from the WDI data base, the study is conducted in ARDL econometric framework which is the latest and preferred method in the stream particularly for the analysis of long run co integrating relationship among the variables.

From the ADF unit root test, it is found that all the variables are non-stationary at their level but stationary after taking their first difference i.e. they are integrated of order one I(1). Then after automatically selecting the optimum lag length to be included, the test for co integration among the variables using ARDL- bound test approach is conducted. From the obtained results, it is found that there existence long run co integrating relationship among the variables at all levels of significance.

Next the stability and diagnosis tests are checked for the models and found that they pass tests for serial correlation, normality tests, and model specification tests and are found to be stable.

In order to achieve the objective of investigating the effect of energy and growth variables to the country's emission of CO_2 under the study period, long run and short run model estimation is carried out.

In the long run the dominant energy source – biomass energy –positively affects emission of the gas. In the short run, modern renewable energy consumption which basically comprises hydropower, helps in the reduction of CO_2 emission in the country. The last energy variable, non-renewable energy, results in increase the emission of CO_2 in the country both in the long and short run in the period under consideration.

Finally, real GDP per capita, which is assumed to significantly affect the emission of CO_2 in Ethiopia, positively affect CO_2 emission in both short and long run. That is the rise in real GDP per capita in the study period increases emission of the gas in Ethiopia.

6.2 Implications

As stated above, non- renewable energy and biomass energy sources which dominates the country's total energy consumption leads to the increase in emission of CO_2 in the study period. It is only modern renewable energy source which negatively influences CO_2 emission justifying the country's aggressive move towards it, at least from emission perspective.

The result for biomass energy sector confirmed the assertion that it is being produced in unsustainable manner by harvesting beyond the sustainable yield. Thus the sector requires further modernization by producing energy from wastes and also by reforesting the trees used for production.

The major non-renewable energy (imported petroleum) results high emission of CO_2 in the country posing further challenges beyond its budgetary and foreign exchange burden to the country. Thus, reliance on this source better be reduced and shifting the sector to renewable alternatives is acceptable from environmental grounds in addition to economic aspect.

Generally, the country's preference and high public investment on modern renewable energy development and modernization of the traditional biomass sector and adjusting the energy mix is appropriate and better be extended.

In this regard, government and various stakeholders need to win the challenges facing the spread of renewable energy technologies and development of the modern renewable energy source. Particularly, high initial investment and development cost, awareness problem among the users, institutional and capacity difficulties, international and regional challenges regarding the development of the hydro and other resources, etc. must be tackled.

In addition, the country's economic growth under the study period results in high emission of CO_2. Hence the general economic activity and urbanization process, energy consumption, industrial production, agricultural development and other sectors and activities in the economy better to be aligned with the country's green growth strategy.

Consequently, the country's ambition of reaching middle income status with lower emission profile can be met by relying on environmentally friendly energy sources which emit lower CO_2 and by generally aliening the country economic activity with the strategy of green growth.

6.3 Future research direction

Given the importance of the area and inconclusiveness of previous studies, future researches better to be done particularly on the multivariate framework investigating the renewable energy–economic growth and environmental interaction simultaneously. In addition, further disaggregation of the energy sector beyond the renewable – non-renewable, like individual treatment of different sources can give further incite to policy makers and stakeholders.

Also, in order to have broad environmental implications of different energy sources, the environmental variable can better be made to represent the broader concept of environment, beyond emission of CO_2.

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APPENDICES

Appendix 1: Detail derivation of the ARDL model for checking the co integrating relationship

Consider a simple dynamic ARDL model describing the relationship between y_t and X_t

$$Y_t = a_0 + a_1 Y_{t-1} + \gamma_0 X_t + \gamma_1 X_{t-1} + u_t \ldots\ldots\ldots\ldots\ldots\ldots\text{eq1}$$

Where; u_t ~ iid (0, σ^2).

The long-run effect is given when the model is in equilibrium. That is let us assume, for simplicity, that

$$X_t^* = X_t = X_{t-1} = \cdots = X_{t-p}$$

Then the above general model will be

$$Y_t^* = a_0 + a_1 Y_{t-1} + \gamma_0 X_t^* + \gamma_1 X_{t-1}^* + u_t \ldots\ldots\ldots\ldots\ldots\ldots\text{eq2}$$

$$Y_t^*(\,1 - a_1) = a_0 + (\gamma_0 + \gamma_1) X_t^* + u_t \ldots\ldots\ldots\ldots\ldots\ldots\text{eq3}$$

$$Y_t^* = \frac{a_0}{1-a_1} + \frac{(\gamma_0+\gamma_1)}{(1-a_1)} X_t^* + u_t \ldots\ldots\ldots\ldots\ldots\ldots\text{eq 4}$$

$$Y_t^* = \beta_0 + \beta_1 X_t^* + u_t \ldots\ldots\ldots\ldots\ldots\ldots\text{eq5}$$

Where; $\beta_0 = \frac{a_0}{1-a_1}$, $\beta_1 = \frac{(\gamma_0+\gamma_1)}{(1-a_1)}$ captures the long run relationship between Y and X.

For the short run model the ECM can be written as;

$$\Delta Y_t = \gamma_0 \Delta X_t - (1 - a_0)(Y_{t-1} - \beta_0 - \beta_1 X_{t-1}) + u_t \ldots\ldots\ldots\ldots\text{eq6}$$

$$\Delta Y_t = \gamma_0 \Delta X_t - \pi(Y_{t-1} - \beta_0 - \beta_1 X_{t-1}) + u_t \ldots\ldots\ldots\ldots\ldots\text{eq7}$$

$$\Delta Y_t = \gamma_0 \Delta X_t - \pi ECT_{t-1} + u_t \text{………….eq 13………………. .eq8}$$

Where $\pi = (1 - a_0)$ is the error correcting parameter which measures the speed of adjustment of the mode and $ECT_{t-1} = Y_{t-1} - \beta_0 - \beta_1 X_{t-1}$ is the error correction term lagged by one period.

For large number of lagged rates, the general ARDL (ARDL (p, q)) will be;

$$\Delta Y_t = \mu + \sum_{i=1}^{p-1} a_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} \gamma_1 \Delta X_{t-i} - \pi \hat{e}_{t-1} + u_t \text{……………eq 10}$$

Or

$$\Delta Y_t = \alpha Y_{t-1} + \gamma X_{t-1} + \sum_{i=1}^{p-1} a_i \Delta Y_{t-i} + \sum_{i=0}^{q-1} \varphi \Delta X_{t-i} + u_i \text{…………eq 11}$$

Which is the unrestricted ARDL (p, q) model for p lagged values of Y_t and q number of lagged values of X_t.

Appendix 2: Bound test result for co integrating relationship

ARDL Bounds Test
Date: 05/23/17 Time: 21:18
Sample: 1983 2014
Included observations: 32
Null Hypothesis: No long-run relationships exist

Test Statistic	Value	K
F-statistic	8.103671	4

Critical Value Bounds

Significance	I0 Bound	I1 Bound
10%	2.45	3.52
5%	2.86	4.01
2.5%	3.25	4.49
1%	3.74	5.06

Appendix 3: Functional form specification test result

Ramsey RESET Test
Equation: UNTITLED
Specification: CO2 CO2(-1) RGDP NREC NREC(-1) NREC(-2) MREC BEC BEC(-1) BEC(-2) C
Omitted Variables: Squares of fitted values

	Value	Df	Probability
t-statistic	2.060700	21	0.0519
F-statistic	4.246483	(1, 21)	0.0519

F-test summary:

	Sum of Sq.	Df	Mean Squares
Test SSR	4.10E-05	1	4.10E-05
Restricted SSR	0.000244	22	1.11E-05
Unrestricted SSR	0.000203	21	9.65E-06

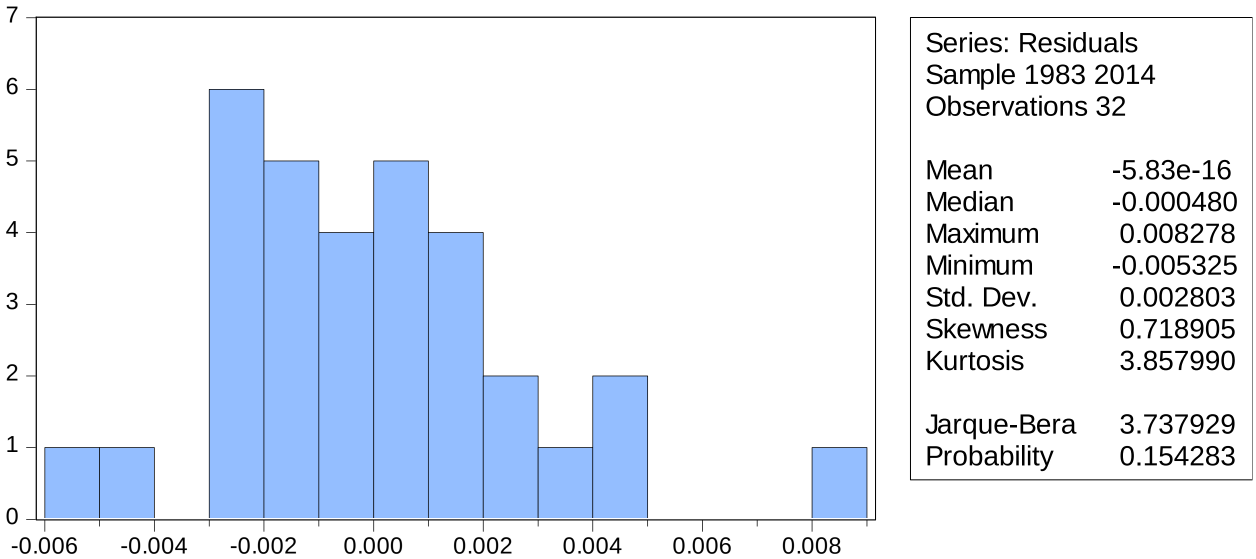
Unrestricted Test Equation:
Dependent Variable: CO2
Method: ARDL
Date: 05/23/17 Time: 21:28
Sample: 1983 2014
Included observations: 32
Maximum dependent lags: 2 (Automatic selection)
Model selection method: Akaike info criterion (AIC)
Dynamic regressors (2 lags, automatic):
Fixed regressors: C

Variable	Coefficient	Std. Error	t-Statistic	Prob.*
CO2(-1)	0.697101	0.191109	3.647666	0.0015
RGDP	5.02E-05	1.81E-05	2.770345	0.0115
NREC	0.003592	0.000837	4.293758	0.0003
NREC(-1)	-0.001528	0.000577	-2.646926	0.0151
NREC(-2)	0.002908	0.000723	4.020602	0.0006
MREC	-0.005884	0.002210	-2.662332	0.0146
BEC	-0.003386	0.008342	-0.405947	0.6889
BEC(-1)	-0.017431	0.018383	-0.948187	0.3538
BEC(-2)	0.054068	0.021439	2.521986	0.0198
C	-15.27825	5.046405	-3.027550	0.0064
FITTED^2	-6.753573	3.277321	-2.060700	0.0519

R-squared	0.981527	Mean dependent var	0.064539
Adjusted R-squared	0.972730	S.D. dependent var	0.018809
S.E. of regression	0.003106	Akaike info criterion	-8.444635
Sum squared resid	0.000203	Schwarz criterion	-7.940788
Log likelihood	146.1142	Hannan-Quinn criter.	-8.277624
F-statistic	111.5786	Durbin-Watson stat	2.012742
Prob(F-statistic)	0.000000		

*Note: p-values and any subsequent tests do not account for model selection.

Appendix 4: normality test result



Appendix 5: test result for serial correlation

Breusch-Godfrey Serial Correlation LM Test:

F-statistic	2.288980	Prob. F(2,20)	0.1273
Obs*R-squared	5.960410	Prob. Chi-Square(2)	0.0508

Test Equation:
Dependent Variable: RESID
Method: ARDL
Date: 05/23/17 Time: 21:26
Sample: 1983 2014
Included observations: 32
Presample missing value lagged residuals set to zero.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
CO2(-1)	0.130022	0.173194	0.750732	0.4616
RGDP	-1.18E-05	1.52E-05	-0.775732	0.4470
NREC	-2.71E-05	0.000451	-0.060111	0.9527
NREC(-1)	0.000130	0.000591	0.220829	0.8275
NREC(-2)	-0.000161	0.000445	-0.362135	0.7210
MREC	-0.001378	0.002362	-0.583601	0.5660
BEC	0.004485	0.008704	0.515251	0.6120
BEC(-1)	-0.004572	0.016304	-0.280403	0.7820
BEC(-2)	0.003746	0.010616	0.352871	0.7279
C	-1.678512	2.698499	-0.622017	0.5410
RESID(-1)	0.012937	0.300105	0.043108	0.9660
RESID(-2)	-0.539763	0.266473	-2.025582	0.0564

R-squared	0.186263	Mean dependent var	-5.83E-16
Adjusted R-squared	-0.261293	S.D. dependent var	0.002803
S.E. of regression	0.003148	Akaike info criterion	-8.404088
Sum squared resid	0.000198	Schwarz criterion	-7.854437
Log likelihood	146.4654	Hannan-Quinn criter.	-8.221895
F-statistic	0.416178	Durbin-Watson stat	2.327870
Prob(F-statistic)	0.931528		

Appendix 6: Long and short run estimation Results

ARDL Cointegrating And Long Run Form
Dependent Variable: CO_2
Selected Model: ARDL(1, 0, 2, 0, 2)
Date: 05/23/17 Time: 21:23
Sample: 1981 2014
Included observations: 32

Cointegrating Form

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(RGDP)	0.000023	0.000013	1.730711	0.0975
D(NREC)	0.002071	0.000422	4.908296	0.0001
D(NREC(-1))	-0.001712	0.000463	-3.701187	0.0012
D(MREC)	-0.003702	0.002078	-1.781432	0.0887
D(BEC)	-0.004177	0.008927	-0.467945	0.6444
D(BEC(-1))	-0.015281	0.010995	-1.389850	0.1785
CointEq(-1)	-0.621734	0.120170	-5.173803	0.0000

Cointeq = CO2 - (0.0000*RGDP + 0.0045*NREC -0.0060*MREC + 0.0215 *BEC -9.8736)

Long Run Coefficients

Variable	Coefficient	Std. Error	t-Statistic	Prob.
RGDP	0.000037	0.000020	1.899676	0.0707
NREC	0.004537	0.000879	5.159870	0.0000
MREC	-0.005954	0.003688	-1.614622	0.1206
BEC	0.021518	0.010170	2.115887	0.0459
C	-9.873606	4.662019	-2.117882	0.0457