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**IMPACT OF RENEWABLE ENERGY AND AGRICULTURE ON CO₂
EMISSION IN SUB-SAHARAN COUNTRIES**

A dissertation submitted to the African Center of Excellence in Energy for sustainable development (ACE-ESD) in partial fulfillment of the requirement for the degree of Master of Science in Energy Economics

By

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DECLARATION

I declare that this dissertation is the result of my own work and has not been submitted for any other degree at the university of Rwanda or any other institution.

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APPROVAL

I certify that the candidate completed the work presented in this research dissertation under my supervision and with my permission before submitting it.

Name : Prof. Fidèle NIYITANGA

Signature : 

Date

DEDICATION

To my beloved husband NIYOMUGABO MAHORO Tharcisse, my family and relatives who always encouraged me to push on with the writing of this project report whenever I contemplated giving up.

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This work has been made possible thanks to the moral, financial, and technical support of a number of people. First and foremost, I want to express my heartfelt gratitude to Almighty God, to whom I owe my life and all good faith. I thank Him for empowering me throughout my academic career and for allowing me to complete this research project in particular.

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May God continue to bless each of you.

ABSTRACT

In recent years, countries have paid increased attention to the contentious issue of green energy in both developed and emerging economies. Green energy is another term for renewable energy. It is defined as an energy that is collected by renewable sources such as wind, waves, geothermal, sunshine, heat, and rain, among others, and does the least amount of harm to nature and the environment. This study explores the impact of renewable energy and agriculture on CO₂ emission in sub-Saharan countries. Panel data for 1990 to 2021 period for 36 Sub-Saharan African nations is used. The data is from world bank development indicator. Ordinary Least square was used to estimate the random effect model used in the analysis. The findings show that 1 % increase of renewable energy is associated with a 2.25 % decline in CO₂ emissions. Furthermore, an increase of 1% in agriculture is associated with an increase of 0.01point percentage of metric tons of CO₂ emissions. This current study provides valuable strategy recommendations for policy makers. Major agricultural reforms including the distribution of solar tube wells to small farmers for irrigation, the use of tunnel farming, and organic farming are required in sub-Saharan in order to reduce CO₂ emissions from agricultural production.

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LIST OF ABBREVIATIONS

CO₂ : Carbon Dioxide

CO₂E : Carbon Dioxide Emission

EKC : Environmental Kuznets Curve

FAO : Food and agriculture organization

OECD: Organization for Economic Co-operation and Development

GDP : Gross Domestic Product

GHG : Green House Gases

IEA : International Energy Agency

IMF : International Monetary Fund

MSP : Mediterranean Solar Plan

RD : Random Effect

REN : Renewable Energy Consumption

UR : University of Rwanda

WDI : World Development Indicator

Chapter 1: GENERAL INTRODUCTION

1.1. Background of the study

Global warming is presently considered to be the most urgent concern by politicians, world leaders, and academics. SSA nations have contributed virtually little to the unprecedented level of global emissions despite the fact that the region is very sensitive to climate change. The top 10 countries most vulnerable to climate change including Sierra Leone, South Sudan, Nigeria, Chad, Ethiopia, the Central African Republic, and Eritrea are all located in the SSA area (Sarkodie, 2018). However, the region's environmental quality has further declined due to large levels of energy poverty, energy inefficiency and unmistakable effects of global warming (Acheampong et al., 2019).

Agriculture and renewable energy are the sectors that are rising up, especially in sub-Saharan countries and impact on the economy in those countries. However, the United Nations Food and Agriculture Organization (FAO) believes that the agricultural sector has a substantial potential to decrease its emissions, including removing 80%–88% of CO₂ emissions that it currently produces (Reynolds & Wenz Lau, 2012).

With more than 600 million people without access to electricity, the SSA area exhibits the highest level of energy poverty (Acheampong et al., 2019). Rising pollution from inefficient energy sources is blamed for many deaths. These energy-related problems are a result of an increase in CO₂ emissions from the production of electricity and heat. The ongoing rise in the ratio of electricity transmission and distribution losses make these negative consequences even worse (Chakamera and Alagededi, 2018).

Agriculture resulted in significant carbon dioxide (CO₂) emissions in practically every region of the world. Agriculture accounts for between 14% and 30% of global greenhouse gas (GHG) emissions due to its substantial usage of fossil fuels (Reynolds and Wenzlau, 2012). Using fuel-powered farm equipment, pumping water for irrigation, holding cattle indoors, and applying nitrogen-rich fertilizers are all factors that contribute to agriculture's high GHG emissions.

The use of the main renewable energy sources in agricultural activities are detailed in (Bayrakc & Koc, 2012):

- i) Solar energy can be used for greenhouse heating and cooling, lighting, product drying, and farm field irrigation;

- ii) Modern biofuels like bioethanol and biogas, and various agricultural residues such as grain dust, wheat straw, and hazelnut shells can be used as sources of energy
- iii) Geothermal energy can serve in aquaculture, in barns, in soil improvement, in the greenhouse, to heat the soil in open fields, and to dry agricultural products;
- iv) Wind energy can be used to generate electricity, irrigate fields and grind some of the hydropower can be used for electricity production, irrigation, drinking water supplies, and facilitates the equitable sharing of water between farmers.

Many regulatory framework improvements have been implemented in order to stimulate greater private sector participation in renewable energy production. Furthermore, these countries have developed ambitious strategic objectives and started large-scale integrated programs with the primary goals of GHG reduction, direct and indirect job creation, industrial development, and human capital improvement. Currently, various sub-Saharan African nations are anticipated to strengthen technical and financial collaboration while also expanding regional markets for renewable energies. It appears difficult for the countries to develop alternatives to energy in their operations given the massive dependency of economies on energy consumption in many areas of manufacturing, technologies, transportation, agriculture, and communication, etc. The consumption of energy by homes is also seen as a fundamental need and a crucial aspect of societal advancement (Xiaohua, & Zhenmin, 2001; Onyinye *et al.* 2018).

This study is embedded with the environmental Kuznets curve (EKC) hypothesis that has received interest from both environmental and economic perspectives (Pate, 2018a, 2018b; Be khet and Othman, 2018; Baleentis *et al.*, 2019). The shift in focus to EKC hypothesis studies resulted from efforts to investigate the relationship between economic development and the environment (Grossman and Krueger, 1991; Madden *et al.*, 2019). According to the EKC, economic growth puts a strain on the environment; however, at a certain point in economic development, the environmental damage caused by economic expansion is mitigated by an increase in the country's income (Ahmad *et al.*, 2017; Al-Murali *et al.*, 2015) (Nur Hilfa *et al.*(2020). Moreover, they agreed to support, develop, and enlarge the share of renewable energy and to develop economies with zero net emissions as soon as possible. In practice, this means that the countries are going to increase their shares of renewable energy and are supposed to decrease their CO₂ emissions.

Many literature found inconclusive result on the impact of agriculture and renewable energy on CO₂ emissions due to the nation structure, data used and economic characteristics. The crucial link between green energy and carbon emissions has been generally acknowledged as a means of enhancing environmental quality by lowering the emissions of harmful greenhouse gases. Numerous researches have found a negative link between using green energy and carbon emissions (Inglesi-Lotz, & Dogan, 2018; Zoundi, 2017; Bento, & Moutinho, 2016). However, other studies have revealed a positive relationship between the variables (Jebli, & Youssef, 2017; Orji, Ogbuabor & Anthony-Orji 2018). According to Reganold and Wachter (2016), Liu, Zhang, and Bae (2017), and Orji et al. (2018), agriculture plays a crucial role in preventing ecological changes. The reliance on agriculture frequently discourages the growth of other industries and provides protection against a number of harmful byproducts of pollution and resource depletion. Additionally, as environmental consciousness has increased, farmers have developed a practice of utilizing their surroundings to the fullest by using superior, environmentally friendly, and regionally appropriate farming systems that have numerous social and environmental advantages. Given the significance of agriculture in sub-Saharan Africa, farmers make very few modern contributions, even though the extensive use of modern techniques—such as improved seed, composts and other agro-synthetic compounds, tools, and irrigation—is expected to significantly reduce the region's rural poverty (Sheahan, & Barrett, 2017).

Further, SSA countries give the utilization of renewable energy a high priority. An increasing number of green activities, such as solar power generation, are being promoted throughout the region (Amankwah-Amoah, 2015). Additionally, it is believed that using renewable energy sources will help the area's economy and reduce poverty (World Bank, 2001). As a result, the SSA region is essential for researching any possible connections between the use of renewable energy and carbon emissions (Deichmann, Meisner, Murray, & Wheeler, 2011; Winarni et al., 2018).

1.2. Problem statement

In sub-Saharan countries, agriculture employs more than half of the total labor force (IMF, 2012) and within the rural population, provides a source of revenue for multitudes of small-scale producers. Smallholder farms constitute approximately 80% of all farms in SSA and employ about 175 million people directly (Alliance for a Green Revolution in Africa, 2014). In many countries, women comprise at least half of the labor force (FAO, 2015). Many studies have been conducted to examine the impact of agriculture on CO₂ emissions, but the findings have been confusing. Some results find a negative

impacts while others are positive but does not work on sub-Saharan countries. Global emissions from agriculture-related land use and land use change in 2018 were close to four Turbocharged diesel CO₂ equivalent. Nearly three-fourths of these worldwide emissions were attributable to deforestation, which is considered to be entirely driven by agriculture in this instance. The remaining one-fourth was brought on by soil erosion and burning. Although agriculture is the primary cause of deforestation worldwide while Methane and nitrous oxide, both potent greenhouse gases, are released in substantial volumes during crop and livestock production, accounting for a combined 5.3 Turbocharged diesel Co₂-equivalent of non-CO₂ emissions in 2018. Livestock production accounts for two-thirds of this total. In instance, CH₄ emissions from enteric fermentation in ruminant livestock's digestive systems remained the single greatest component of farm-gate emissions in 2018 (2.1 Gt CO₂eq). At the regional and local levels, significant non-agricultural causes might exist, making the world total likely an overestimate. For about 2.4 billion people in underdeveloped nations, biomass is their primary source of energy (IEA, 1998). Furthermore, reliance on traditional biomass has major health consequences for rural households, such as chronic respiratory ailments and eye infections.

The potential renewable energy technologies are the greatest at the level. The use of renewable energy technologies for agriculture production means that farmers can undertake more value-added activities (grinding, milling, drying, storage) and are able to access water through the use of solar pumps for irrigation and clean drinking water. Climate change poses a serious threat to Africa's energy security due to the high dependence on traditional biomass. This is a key driver of deforestation, which further exacerbates climate change through CO₂ emissions.

Hydropower is another important source of energy in a number of African countries, mainly for electricity generation. Climate change has already had an impact on hydroelectric energy output, as evidenced by recent droughts across the region, which damaged generation capacity in many nations, leading in blackouts and load shedding. Furthermore, variable rainfall patterns and long-term droughts can restrict hydroelectric output and cause longer outages. Given Africa's strong reliance on agriculture for livelihoods and different studies on the impact of agriculture and usage of renewable energy on CO₂ emissions that produced inconclusive results (Danish et al., 2019), this research aims to examine the impact of renewable energy and agriculture on CO₂ emissions in Sub-Saharan countries. What are the consequences of renewable energy and agriculture on Co₂ emission in Sub Saharan Africa?

1.3. Objectives of the study

1.3.1. General objectives

The main objective of this study is to examine the impact of renewable energy and agriculture on CO₂ emission in Sub-Saharan countries

1.3.2. Specific objective

This study has the following specific objectives:

- i. To examine the impact of agriculture on CO₂ emissions
- ii. To analyze the impact of renewable energy on CO₂ emissions

1.4. Research hypothesis

1. The agriculture sector in Africa does greatly contribute to CO₂ emissions
2. The use of renewable energy in Africa does lead to the reduction in CO₂ emissions

1.5. Significance of the study

This study is of relevance to concerned sub-Saharan African countries, and Advocacy groups in energy sector. It is expected to guide the policymakers on enhancing the use of renewable energy, agricultural productivity and environment quality of sub-Saharan countries. The findings of this study are of great importance to the public as they can be used to improve on the development of green agriculture, renewable energy environment protection.

1.6. Scope and limitation of the study

This research covers the impact of renewable energy and agriculture on CO₂ emissions in sub-Saharan countries from 1990 to 2021. During this study, there have been some limitations observed like limited resources and time, and it was not possible to cover all developing countries that's why this research focused and limited to sub-Saharan Africa.

1.7. Organization of the Study

In addition to conclusion and recommendations, this thesis is divided into four chapters. The first chapter discusses the study's background, problem statement, research questions and objectives, scope and limitation, hypotheses, and significance of the study. The second chapter reviewed the literature on the impact of renewable energy, agriculture, and CO₂ emissions. Further, this chapter discusses the

study's theoretical and conceptual framework. The third chapter discusses the methodology. It includes data type and source, variable definition and description, and model specification. The fourth chapter cover research findings and discussion.

CHAPTER 2: LITERATURE REVIEW

2.1. Definition of key concepts

– Energy

The concept of energy means normally the state of making something active through application of force. In this perspective, energy acts as the conserved quantity which is converted in a form but not destroyed (Mendy, 2014). On the other hand (Buhaan, 2015) defines energy as all source of power that makes activities start their motions which is delivered from utilization of physical and chemical sources especially to provide light and heat or to make the engine-attached devices to work.

– Renewable energy

The definition of renewable energy is largely uncontested, with broad agreement on what constitutes renewable energy. Renewable energy is defined by the International Renewable Energy Agency as "energy derived from natural processes that are replenished at a faster rate than they are consumed," and examples of renewable energy include solar, wind, geothermal, hydro, and biomass (IEA, 2018b).

– Renewable energy consumption

The renewable energy consumption is the practice of using the unlimited sources of energy for personal uses, industrial running, street lighting, cooking and cooling. This economic use of renewable source of energy ensures the sustainable development which is the development target of maximizing utilities by current generation but without compromising what will be used by future generation. Therefore, the use of renewable energy is beneficial to human kinds through generation of outputs and saves the environment from being affected by the greenhouse gases (Cucchiella, 2018).

– Agriculture

The Oxford English Dictionary of 1971 defines agriculture as science and art of cultivating the soil, including related activities such as crop gathering and livestock rearing; tillage, husbandry, farming. It includes the preparation of plant and animal products for people to use and their distribution to markets. Agriculture provides most of the world's food and fabrics. Agriculture can help reduce poverty, raise incomes and improve food security of the world's poor, who live in rural areas and work mainly in farming.

– **Co2 (carbon dioxide)**

Carbon dioxide is a colorless, odorless gas that is produced by the combustion of carbon and organic substances, as well as through breathing. It exists naturally in the atmosphere and is absorbed by plants during photosynthesis (Danish et al., 2018). It is a chemical compound made up of molecules that each have one carbon atom covalently double bonded to two oxygen atoms. It is found in the gas state at room temperature. It is a heavy colorless gas CO₂ that does not support combustion, dissolves in water to form carbonic acid, is formed especially in animal respiration and in the decay or combustion of animal and vegetable matter, is absorbed from the air by plants in photosynthesis, and is used in the carbonation of beverages (Omae, 2006). In the air, carbon dioxide is transparent to visible light but absorbs infrared radiation, acting as a greenhouse gas. Greenhouse gases, both manufactured and natural, have been classed as gaseous components of the atmosphere. These elements are known to absorb and emit infrared radiation at specified wavelengths within the range of wavelengths emitted by the Earth's clouds, atmosphere, and surface. Greenhouse gases are still a substantial contribution to climate change and global warming ((Paiva S. V., 2014) and (Hossain H, 2012). Carbon dioxide emissions are the primary cause of global climate change. Global climate change is mostly caused by carbon dioxide emissions. To avoid the worst effects of climate change, it is widely accepted that the world must reduce emissions as quickly as possible. However, the distribution of this responsibility across localities, governments, and individuals has long been a source of contention in international forums.

2.2. Impact of agriculture on CO2 emissions

Agricultural energy-related CO₂ emissions are the CO₂ emissions caused by the use of diesel, oil, natural gas, and other fossil fuels in agricultural production (Huang et al., 2019). The direct agricultural CO₂ emissions are caused by the use of fossil energy in the utilization of land and water resources, which has previously been the main component of agricultural CO₂ emissions (Glenk et al., 2014). The reason for this is that the agricultural sector's production mode has shifted to modern agriculture, characterized by mechanization, which has not only improved agricultural production efficiency and farmer income, but has also led to agricultural machinery's reliance on energy consumption (Yang et al., 2013).

Agriculture is vital to both developed and developing countries. Limiting agricultural production is not a long-term plan (Sertoglu and Dogan, 2016). More agricultural productivity, paradoxically, needs

increased energy consumption and, as a result, higher emissions (Zhang et al., 2019). Furthermore, increased use of fertilizers and pesticides, as well as irrigation and farm mechanization, were the main culprits for the increase in CO₂ emissions in crop production (Kern et al., 2012), whereas CO₂ is generated by farming activities in animals (Watts, 2019).

2.3. Agriculture and climate change

Climate change is regarded as the greatest challenge confronting global society, both in terms of preventing future changes and adapting to changes that are already occurring or are on the horizon. A variety of adaptive strategies must be considered to mitigate the effects of climate change on agricultural production and productivity. Changing cropping calendars and patterns will be the best immediate option with available crop varieties to mitigate the impact of climate change. It is also important to consider options such as introducing new cropping sequences, late or early maturing crop varieties depending on the available growing season, conserving soil moisture through appropriate tillage practices, and efficient water harvesting techniques.

Long-term strategy should be to develop heat and drought tolerant crop varieties by utilizing genetic resources that may be better adapted to new climatic and atmospheric conditions. Genetic manipulation may also aid in capitalizing on the beneficial effects of increased CO₂ on crop growth and water use. One promising approach would be to use gene pyramiding to improve plant adaptation to climatic change inputs. As a result, there is an urgent need to address climate change and variability issues holistically by improving the natural resource base, diversifying cropping systems, adapting farming systems approaches, strengthening the extension system, and providing institutional support. To improve agricultural productivity of the country, advances in biotechnology and information technology must be used for better agricultural planning and weather/climate-based management (Rama Rao, 2019).

2.4. Renewable energy and CO₂ emissions

Numerous studies have looked at the connection between renewable energy, agriculture and emissions of carbon in more recent literature. Many authors found that renewable energy consumption decreases CO₂ emissions For instance Chen et al. (2019) explores the relationship between renewable energy, GDP, trade, and CO₂ emissions in China using the autoregressive distributed lag (ARDL) bounds technique and vector error correction model (VECM) for the years 1980–to 2014. The results show

that renewable energy and trade has a negative impact on emissions, while GDP has an inverted U-shaped relationship with CO₂ emissions. The Granger causality tests show that there is a bi-directional relationship between renewable energy, trade, and CO₂ emissions. Additionally, Bilan et al. (2019) explores the effect of renewable energy, GDP growth on CO₂ emissions in EU and potential EU member states over the period 1995–2015. Using cointegration and other empirical methods such as VECM, the authors show that renewable energy adoption leads to improvement in environmental quality (decrease in CO₂ emissions). Dong et al. (2018) explores the importance of renewable energy in mitigating CO₂ emissions in the context of EKC in China over the years 1993–2016. Renewable energy decreases CO₂ emissions both in short- and long-run. In contrast, fossil fuel consumption leads to an increase in CO₂ emissions.

2.5. Review of empirical studies on renewable energy, agriculture and CO₂ emissions

Several recent studies have suggested that boosting agricultural productivity could be a significant, yet underappreciated, source of global GHG mitigation (e.g., Wise et al. 2009; Burney, Davis, and Lobell 2010; Choi et al. 2011; Havlik et al. 2013). The majority of the literature focuses on the effect of exogenous agricultural productivity gains in minimizing farmland expansion and hence avoiding the related carbon dioxide (CO₂) emissions. Hertel (2012) recently demonstrated in a single commodity agricultural model that farmland expansion necessarily declines with higher productivity only if agricultural demand is inelastic and productivity gains are globally consistent. When productivity changes vary across locations with variable yields, land supply elasticities, and emission intensities per unit of output, the GHG consequences of worldwide farmland conversion become more problematic (Hertel, 2012).

When the livestock sector and non-CO₂ emissions from nutrient treatments on crops, as well as animal enteric fermentation and waste management, are explicitly accounted for, the GHG dynamics become more complex. This introduces the emission trade-offs associated with substituting alternative GHG emitting inputs for land, such as fertilizer, on the input side (Popp et al;2010).On the output side, this introduces variations in emissions due to the shifting distribution of food consumption across commodities with varying emission intensities (GHG emissions per unit of output), as prices decline as productivity rises and incomes rise over time. Notably, rising livestock and agricultural productivity (through feed demand) lower livestock production costs, while rising incomes (especially in emerging nations) move food demand toward animal sources (Muhammad et *al.*, 2011). Reflective cattle (and

rice) emit approximately five times more emissions than all other crops on a worldwide scale (and no ruminant livestock).

According to Paustian *et al.* (2006), the agriculture sector can help to mitigate climate change by increasing carbon sinks and sequestering carbon through cleaner agricultural methods. This potential is enhanced by the use of renewable energy to power agricultural tools and other types of machinery, reducing the demand for fossil fuels while having a low environmental impact (Liu *et al.*, 2017; Dong *et al.*, 2018). Renewable energy is heavily marketed in a variety of industries, including agriculture (Qiao *et al.*, 2019). As a result, to meet the growing demand for clean energy, the world's renewable energy output has increased (Al-Mulali *et al.*, 2016). Furthermore, renewable energy plays an important role in lowering CO₂ emissions, particularly in the EKC environment (Baek, 2016). Incorporating renewable energy and agriculture into this study's EKC model is critical for achieving sustainable agriculture while reducing CO₂ emissions.

From 2004 to 2017, Rokicki *et al.* (2020) investigated the relationship between agricultural greenhouse gas emissions, economic development, and agricultural production factors in the European Union. According to the report, agricultural greenhouse gas emissions decreased modestly across the EU from 2004 to 2017. However, the adjustments were not uniform. Agriculture-related greenhouse gas emissions increased in developing nations while maintaining flat in wealthy nations.

Environmental and economic perspectives have focused on the environmental Kuznets curve (EKC) theory (Pata, 2018a, 2018b; Bekhet and Othman, 2018; Baleentis *et al.*, 2019). As a result of efforts to examine the relationship between economic development and the environment, the emphasis on EKC hypothesis research has shifted (Grossman and Krueger, 1991; Madden *et al.*, 2019). Economic growth, according to the EKC, has a negative influence on the environment; but, at some point in economic development, the environmental harm produced by economic expansion is balanced by an increase in the country's GDP (Ahmad *et al.*, 2017; Al-Mulali *et al.*, 2015). While economic development activities have a negative impact on the environment, the EKC theory contends that economic expansion can also be used to mitigate environmental degradation (Kuznets, 1955). The EKC theory warrants further investigation using a variety of econometric methodologies to validate the relationship between growth and the environment (Mikayilov *et al.*, 2018; Al-Mulali *et al.*, 2016; Ahmad *et al.*, 2016; Apergis, 2016).

When it is unclear which variables contribute to CO₂ emissions, the EKC hypothesis allows for investigation and rigorous modification of the original EKC model by incorporating other possible CO₂ emission drivers into the growth-environment nexus to discover the best match. Previous study has identified population, foreign direct investment, and financial development as drivers to CO₂ emissions. Other research, however, have attempted to explore the relationship between environmental deterioration and economic development by including other CO₂ emissions drivers, such as agriculture, urbanization, and renewable energy, into the EKC hypothesis's setting in a single study.

Liu *et al.* (2017) investigated the relationship between green energy, non-renewable energy, and agriculture on environmental degradation in the ASEAN region. The authors used carbon-di-oxide emanation to assess degradation. The research used data from 1970 to 2013. Using panel cointegration, FMOLS, and DOLS econometrics, the study found that all variables have a significant influence on environmental degradation. The findings specifically established that while an increase in green energy and agriculture is critical to reducing carbon emissions, non-renewable consumption increased it.

Additionally, Rida Waheed *et al.* (2017) used the Autoregressive Distributed Lag model to examine the long-run and short-run effects on CO₂ emission of renewable energy consumption, agriculture production, and forest in Pakistan from 1990 to 2014, and discovered that in the long run, renewable energy consumption and forest have negative and significant effects on CO₂ emission, indicating that CO₂ emissions can be reduced by increasing renewable energy usage. In contrast, agricultural output has a long-term positive and considerable effect on CO₂ emissions, implying that agricultural production is also a key carbon source in Pakistan.

Bilgili *et al.*, (2016) examined the relationship between the rise of renewable energy production and environmental deterioration. The scientists employed carbon-di-oxide emission as a proxy for deterioration. Data from seventeen OECD countries between 1977 and 2010 were used in the study. The study's findings showed that renewable energy has a considerable impact on the rate of environmental degradation after using the econometrics of panel FMOLS and DOLS. The results, in particular, showed that a rise in green energy is essential to lowering carbon emissions in the selected

countries. Additionally, the findings validated the EKC curve, which showed a connection with an inverted U-shaped pattern.

Jebli & Youssef (2015) investigated the relationship between green energy utilization, output growth, and environmental degradation in Tunisia. The authors used data from 1980 to 2009 to measure degradation using carbon-di-oxide as a proxy. Using the methods of ARDL bound testing and VECM, the study's findings revealed that green energy and non-renewable energy have a significant influence on environmental degradation. The findings specifically established that increasing green energy marginally decreased carbon emissions, whereas non-renewables significantly increased them.

On the other hand, some authors found that renewable energy increase CO₂ emission for instance Mehdi Ben Jebli et Slim Ben Youssef (2019) analyzed the role of renewable energy and agriculture in reducing CO₂ emissions in North Africa countries on the period 1980-2011 using Granger causality studies indicate that there is a unidirectional causal relationship going from agricultural to GDP, from GDP to renewable energy use, and from renewable energy consumption to agriculture in short term. In the long run, there is a bidirectional causative relationship between agricultural and CO₂ emissions, a unidirectional causal relationship exists between renewable energy, output, and agriculture and emissions. According to long run parameter estimates, an increase in the GDP or in the consumption of renewable energy (combustible energy and waste) results in an increase in CO₂ emissions, whereas an increase in the agricultural value-added results in a reduction.

Jebli & Youssef (2017) also investigated the relationship between green energy, agriculture, and environmental degradation in North Africa countries. The authors used carbon-di-oxide emanation to quantify degradation. The study analyzed data from five North African economies from 1980 to 2011. Using panel OLS, FMOLS, and DOLS econometrics, the study's findings revealed that renewable energy has a significant to influence environmental degradation. Furthermore Zoundi (2017) looked into the relationship between renewable energy, output growth, and environmental degradation. The author used the measure of carbon-di-oxide emanation to assess degradation. The study used data from twenty-five African countries from 1980 to 2012. Using panel cointegration and DOLS econometrics, the study's findings revealed that renewable energy has a significant influence on environmental degradation. The findings specifically established that an increase in green energy had a negative effect on the levels of carbon emissions in the sampled countries.

Apergis & Payne (2010) examine the relationship between renewable energy, CO2 emissions, economic growth, and nuclear energy from 1984 to 2007. Granger's causality tests show that renewable energy does not help to reduce CO2 emissions in the short term. Increasing environmental concerns and global dependence on electricity have directed attention to the importance of producing renewable energy in a sustainable manner with low emissions of greenhouse gases, particularly CO2. Achieving sustainable renewable energy systems will require significant changes to the power sector to integrate larger amounts of renewable energy sources (RESs), and promote investments in REP. The key issues regarding integration of renewable energy in power systems and current developments in the electricity supply industry are discussed.

2.6. Conceptual framework

The conceptual framework for this investigation is projected in this section. The quality of the input determines the quality of the product, which is impact of CO2 emission in Sub-Saharan Africa from 1990 to 2021 in this study. Renewable energy and agriculture will be working as determinants of CO2 emissions. They affect CO2 emissions in each user category and household sector mainly in activities of lighting, cooking, /farming, livestock, and forest. The variables of interest and the study's analytical framework will be determined by this conceptual framework.

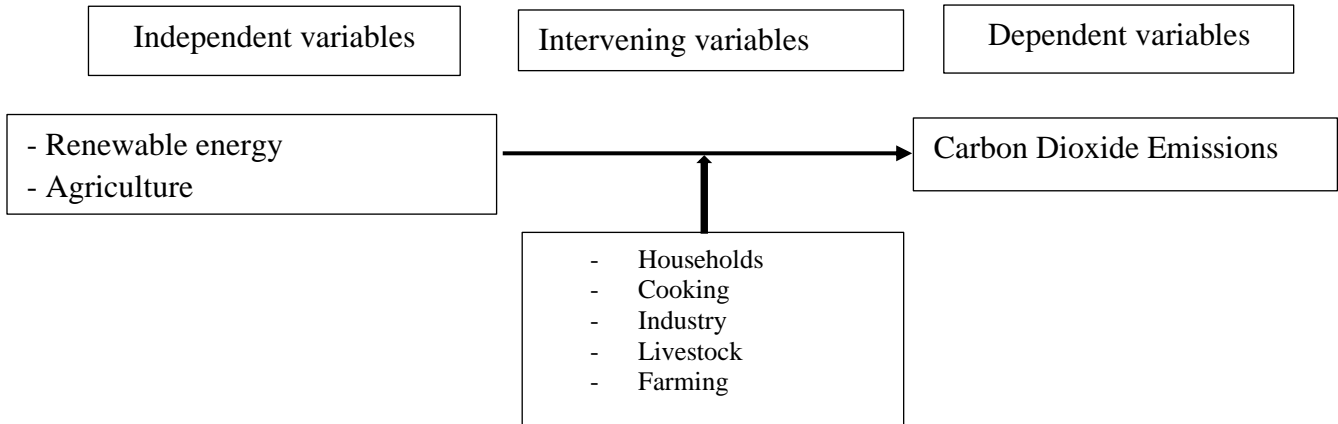


Figure 1: Conceptual framework

Chapter 3. RESEARCH METHODOLOGY

3.1. Source of data

The World Development Indicators database of the World Bank served as the source of the data for this study. It is the principal collection of development indicators used by the World Bank. Panel data for thirty-six (36) African nations is used in this study including: Benin, Botswana, Burkina Faso, Burundi, Cabo Verde, Cameroon, Chad, Comoros, Congo Republic, Cote d'ivoire, Eswatini, Ethiopia, Gabon, Gambia, The Ghana, Guinea, Guinea-Bissau, Kenya, Lesotho, Malawi, Mauritius, Mozambique, Namibia, Nigeria, Rwanda, Senegal, Seychelles, Sierra Leone, South Africa, Sudan, Tanzania, Togo, Uganda, Zambia, Zimbabwe. The data covers 1990 to 2021 period.

Table 1: Measurement units of the study variables and data collection sources

Variables	Measurement unit	Period	Sources
Co2 emission	(In Metric ton)	1990-2021	(WDI)
Renewable energy consumption	(% total final energy consumption)	1990-2021	(WDI)
Agriculture	(% of GDP)	1990-2021	(WDI)

3.2. Model Specification

To achieve our goal and derive the link between renewable energy consumption and agriculture, we estimated the following equation. Because there are repeated observations at the country level, we used a random-effects (RE) method to estimate and evaluate the effect of renewable energy consumption and agriculture on carbon dioxide emission, which includes estimating the following conditional outcome equation:

$$Y_{\pi t} = \alpha 1_{\pi} + \beta_1 X_{\pi t} + \beta_2 REN_{\pi t} + \varepsilon_{\pi t} \text{ (Eq.1)}$$

The above equation for random effects (country and survey year) where Y_t is the outcome variable of interest representing CO2 emission of a specific country is for a country's random effects, while t stands for the random effect of the survey year. The country impact incorporates all observable and unobservable time-invariant country characteristics that might influence renewable energy use in the nation. The year random effect, on the other hand, is utilized to account for time variable factors that can affect the use of renewable energy. REN_t is a different interesting variable (Renewable Energy consumption in the country).

The model also includes the country characteristics that change over time, as indicated by X_t . Agriculture is one of the national characteristics, and it is an unobserved element influencing the sustainability of the environment indicator Y_t . The dependent variable in this study was CO2 Emission, hence the function for the study was modelled as follows:

$$CO2 = f(AGR; REN) \text{ (Eq.2)}$$

$$CO2_{\pi t} = \alpha_{\pi} + \beta_1 REN_{\pi t} + \beta_2 AGR_{\pi t} + \varepsilon_{\pi t} \text{ (Eq.3)}$$

The variables were changed into logarithmic form to incorporate elasticity, changing Eq (2) into a log-linear specification, and the empirical model was as follows.

$$LnCO2_{\pi t} = \alpha_{\pi} + \beta_1 \ln REN_{\pi t} + \beta_2 \ln AGR_{\pi t} + \varepsilon_{\pi t} \text{ (Eq.4)}$$

Where $CO2$ signifies carbon dioxide emissions, β is an intercept, 1, 2, denote the elasticity coefficients of agriculture (AGR), renewable energy (REN), t denotes time period, and the final factor ε denotes an error term.

CHAP 4. FINDINGS PRESENTATION, INTERPRETATION AND DISCUSSION

4.1 Descriptive statistics

Table 1 shows the results associated with the estimations. As can be seen from the table, the most notable estimation provides concise summaries of the mean, standard error, minimum and maximum values.

Table 2 : Descriptive statistics of the variables

Variable	Obs	Mean	Standard. deviation	Min	Max
Co2	1,080	1.07	1.84	0.02	8.57
Renewables EC	1,080	64.99	26.57	0.71	98.30
Agriculture	1,080	21.27	13.67	1.79	63.83

The descriptive statistics for the variables used in this study are shown in Table 2. Whereas CO₂ emissions (CO₂) are measured in metric tons per capita, renewable energy consumption (REN) is measured in % of total final energy consumption while agriculture is measured in % of GDP. The mean value of CO₂ emissions over the sample period and across the 36 countries is 1.07 metric ton of CO₂ equivalent, which has a high global warming potential. CO₂ emissions range from 0.02 to 8.57 metric tons. The standard deviation of 1.84 metric per ton of CO₂ emissions demonstrates the degree of variability, indicating that the data is not distributed away from the mean value. The mean value of renewable energy consumption is 64.99 % of total energy consumption, and the variation of renewable energy consumption ranges between 0.71 and 98.303% of total energy consumption, indicating that renewable energy consumption deviates from its mean value by 26.57% of total energy consumption. According to descriptive statistics across all countries, the mean value of agriculture is 21.27 percent of the gross domestic product (GDP), with variation ranging between 1.79 and 63.83 percent of the GDP, and the degree of variability indicating that agriculture is 13.67 percent of the GDP away from its mean (GDP).

4.2. Analysis of the renewable energy consumption and farming effect on CO2 emission

Table 3: Impact of Renewable energy and agriculture on co2 emission in sub-Saharan countries

Variables	Random Effect
Renewable energy	-0.0225*** (0.00586)
Agriculture	0.000101 (0.00295)
Constant	2.535*** (0.545)
Observations	1,080
Number of country id	36

Robust standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Random effect results from table 3 showed that statistically and significantly 1% increase of renewable energy is associated with a 2.25 % decline in CO2 emissions. This result indicate that more renewable energy utilization will increase other economic activities with less CO2 emission in sub-Saharan countries. These results are supported by the findings of Mourshed & Quddus (2009; Asongu et al. (2019); Gholamreza & Muhammad (2019) and Bölük & Mert (2014). Furthermore, an increase of 1% in agriculture is associated with an increase of 0.01 point percentage of metric tons of CO2 emissions. These results do corroborate the findings by Gholamreza & Muhammad (2019) who found a positive association between agriculture and co2 emission on the case of sub-Saharan countries. Our findings back up Holly's (2015) claims that nitrous oxide and methane emissions from soil management and livestock practices are significant contributors to CO2 emissions. Additionally, the agriculture industry emits CO2 since it employs non-renewable energy sources like fuel and oil for irrigation. Last but not least, farmers utilize fertilizers with high nitrogen to protect their crops, but these fertilizers also increase CO2 emissions.

CHAPTER 5. CONCLUSION AND RECOMMENDATION

The advantages of renewable energy have been carefully researched, but the use of renewable energy has received less attention, particularly in Sub-Saharan Africa. By employing panel data for the 1990–2021 time period and the regression equation, we have examined the relationship between the use of renewable energy and agriculture and CO₂ emissions. A random-effects (RE) method was employed to estimate and evaluate the effect of renewable energy consumption and agriculture on carbon dioxide emission.

The findings show a negative impact of total renewable energy consumption to CO₂ emission and positive impact of agriculture to CO₂ emission. An increase in renewable energy consumption leads to a decrease in CO₂ emissions while an increase in agriculture practice leads to increase in CO₂ emissions.

The fact that renewable sources of energy reduce CO₂ emissions suggests that policies should be tailored in a way that encourages the replacement of non-renewable energy sources with renewable ones in order to reduce CO₂ emissions. Making environmentally responsible policy choices intended to promote the use of renewable energy sources like solar and wind power for the generation of electricity is one example of a policy that can be put into place for this objective. Since the industry is one of the main producers of CO₂ emissions both in sub-Saharan Africa and the rest of the world, adopting green energy sources in the sector also lowers CO₂ emissions in the industries. In order to reduce CO₂ emissions, governments should also research the viability of using electric vehicles in the area and the potential adoption of such vehicles. On the other hand, major agricultural reforms are required in sub-Saharan, including the distribution of solar tube wells to small farmers for irrigation, the use of tunnel farming, and organic farming in order to reduce CO₂ emissions from agricultural production.

REFERENCES

- Balestra, P., & Nerlove, M. (1966). Pooling cross section and time series data in the estimation of a dynamic model. *Journal of the econometric society*, 585-612.
- Bilan, Y. S. ((2019)). Linking between renewable energy, CO2 emissions, and economic growth: Challenges for candidates and potential candidates for the EU membership. *Sustainability*, 11(6), 1528.
- C. A. Rama Rao, B. M. (2019). *Climate change and Agriculture* .
- Danish, M. G. ((2017)). Thermal analysis turning of AZ31 magnesium alloy under dry and cryogenic conditions. ., *The International Journal of Advanced Manufacturing Technology*, 91(5), 2855-2868.
- DICTIONARY, O. E. (1971). (*The Oxford English dictionary*. Oxford: Oxford University Press.
- Dreher, A., & Jensen, N. M. (2007). Independent actor or agent? An empirical analysis of the impact of US interests on International Monetary Fund conditions. *The Journal of Law and Economics*,, 50(1), 105-124.
- Popp, Alexander, Hermann Lotze-Campen, and Benjamin Bodirsky. "Food consumption, diet shifts and associated non-CO2 greenhouse gases from agricultural production." *Global environmental change* 20.3 (2010): 451-462.
- Harris, T. &. (2014). *Africa agriculture status report: Climate change and smallholder agriculture in Sub-Saharan Africa*.
- Kern, M., Noleppa, S., & Schwarz, G. (2012). Impacts of chemical crop protection applications on related CO2 emissions and CO2 assimilation of crops. *Pest management science*,, 68 (11), 1458-1466.
- Lichtenberg, E. (2002). Agriculture and the environment. *Handbook of agricultural economics*, 2, 1249-1313.
- McGuire, S. (2015). FAO, IFAD, and WFP. (2015). The state of food insecurity in the world 2015: meeting the 2015 international hunger targets: taking stock of uneven progress. Rome: FAO. *Advances in Nutrition*, 6(5), 623-624.
- Mourshed, M., & Quddus, M. A. (2009). Renewable energy RD&D expenditure and CO2 emissions in 15 European countries. *International Journal of Energy Sector Management*.
- Omae, I. (2006). Aspects of carbon dioxide utilization. *Catalysis Today*, 115(4), 33-52.

- Ridzuan, N. H. A. M., Marwan, N. F., Khalid, N., Ali, M. H., & Tseng, M. L. (2020). Effects of agriculture, renewable energy, and economic growth on carbon dioxide emissions: Evidence of the environmental Kuznets curve. *Resources, Conservation and Recycling*, 160, 104879.
- Rokicki, T., Koszela, G., Ochnio, L., Golonko, M., Żak, A., Szczepaniuk, E. K., ... & Perkowska. (2020). A Greenhouse Gas Emissions by Agriculture in EU Countries. 22.
- Ullah, A., Khan, D., Khan, I., & Zheng, S. (2018). . Does agricultural ecosystem cause environmental pollution in Pakistan? *Environmental Science and Pollution Research*, 25(14), 13938-13955.
- Ulucak, R., & Khan, S. U. D. (2020). Determinants of the ecological footprint: role of renewable energy, natural resources, and urbanization.,. *Sustainable Cities and Society*, 54, 101996.
- Waheed, R. C. (2018). Forest, agriculture, renewable energy, and CO2 emission. *Journal of Cleaner Production*, 172, 4231-4238.
- Wang, B., & Wang, Z. (2018). Imported technology and CO2 emission in China. *Renewable and Sustainable Energy Reviews*, 82, 4204-4214.
- Zafeiriou, E., & Azam. (2017). CO2 emissions and economic performance in EU agriculture. *Ecological Indicators*, 81, 104-114.