UNIVERSITY of RWANDA COLLEGE OF SCIENCE AND TECHNOLOGY ACE-ESD AFRICAN CENTER OF EXCELLENCE IN ENERGY FOR SUSTAINABLE DEVELOPMENT

EFFECTS OF ENERGY CONSUMPTION ON CARBON EMISSIONS IN RWANDA

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In partial fulfillment of the requirement for the degree of MASTERS OF SCIENCE IN ENERGY ECONOMICS

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DECLARATION

I, the undersigned, declare that this Project is my original work, and has not been presented for a degree in University of Rwanda or any other universities. All sources of materials that are used for the thesis work have been fully acknowledged.

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APPROVAL

Date of Submission: November 8, 2022

This Dissertation has been submitted for examination with my approval as a university advisor.

Prof. NIYITANGA Fidèle

Thesis Advisor Signature

DEDICATION

This work is first and foremost dedicated to the Almighty God for the strength and wisdom he gave me.

I also dedicate this work to my Mother AKIMANA M. José and my Sisters for their love and moral support. It is ultimately dedicated to my uncle Mr. Innocent GASANGWA and his Family and My Aunt Dominique NGWINONDEBE for their outstanding support in my entire life. It is also dedicated to my Employer Mr. Epimaque KARENZI for his outstanding support in completion of the study.

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The accomplishment of this Dissertation would not happen without the tireless support and guidance of my supervisor Professor NIYITANGA Fidèle whom I convey my deepest thanks.

I am grateful to the all the staff of University of Rwanda, and all of the lecturers in masters of science in Energy Economics, in the African Center of Excellence in Energy studies for sustainable development (ACE-ESD) for having done their best in order to provide me with knowledge that helped to the successful completion of dissertation. K Line Rwanda Ltd, my current employer, is hereby recognized for giving me enough time to follow my postgraduate studies.

Above all, I thank the Almighty God for giving me health and energy in the course of my research.

ABSTRACT

The relationship between the use of energy, GDP and CO_2 emissions in Rwanda within side the duration of 1990-2019 were analyzed by the use of VECM. Primarily, the main problem leading to performing this study was to discover the cause of CO_2 emissions in Rwanda, referring on current status of CO_2 emissions which was 0.08metric tons in 2020. The main goal for the research is to discover the effects of energy usage in Rwanda on CO_2 emissions in atmosphere. Furthermore, other objective is the analysis of causal relationship among GDP and CO_2 emissions. One of the recognize methods of analyzing causal relationship scenarios known VEC model were used to analyze the Effects of Energy usage on CO_2 Emissions in Rwanda. With the help of VECM, the results show that there is long-term correlation among GDP and CO_2 emissions. It turned into determined that the rise of 1.07% of Energy consumed (in TJ) is associated with a rise of 1% of million tons of CO_2 emissions. Findings confirm that more energy use results in more CO_2 emissions. However, the rise of 0.02% in GDP per capita is associated with 1% increase of metric tons of carbon emitted in atmosphere. Moreover, in short-run analysis energy usage same as GDP per capita resulted in CO_2 emissions. In short, increase of GDP per capita requires energy usage; some of the energy used generates CO_2 emissions.

The researcher recommends that the government should enforce policies and strategies related to the use of green energy in order to reduce CO_2 emissions. Society is recommended to reduce the use of oil fueled vehicles in favor of charged vehicles and motor cycles.

Key words: Energy consumption, CO_2 emissions and GDP

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LIST OF ABREVIATIONS

ACEESD: African Center of Excellence in Energy studies for sustainable development

GDP: Gross Domestic Product

CO_2: Carbon Dioxide

VECM: Vector Error Correction Model

TJ: Tera Joule

MININFRA: Ministry of Infrastructure

MW: Mega Watt

REG: Rwanda Energy Group

USAID: United State Agency for International Development

GHG: Green House Gases

REMA: Rwanda Environmental Management Authority

MINIRENA: Ministry of Natural Resources

NDBP: National Domestic Biogas Program

LPG: Liquefied Petroleum Gas

PV-system: Photo-Voltaic system

WDI: World Development Index

VUP: Vision Umurenge Program

IMF: International Monetary Fund

EKC: Environnemental Kuznets Curve

ARDL: Auto-Regressive Distributed Lagged

ADF: Augmented Dickey Fuller

EC: Error Correction

CHAPTER ONE: INTRODUCTION

1.1. Background of the study

Rwandan economy was highly affected by Genocide against Tutsi in 1994; however the government of Rwanda tried to stabilize its economy after the Genocide. In the ways of overcoming the economic shock in 1994, energy sector played an important role towards the economic development of the country. It was the fact that through the Ministry of Infrastructure, government targeted 100% of electricity access by 2024 from 59.7% in 2020 (MININFRA, 2021). The Electricity generated in Rwanda in 2020 was 228.2MW, government target generation capacity of 556MW in 2024. The main sources of electricity in Rwanda are Hydro-electricity, Solar, Methane gas and Biomass. The dominate origin of electricity is Hydro-power with 41.45%, Thermal sources with 25.74%, Methane gas with 13.04%, Solar with 5.28% and Peat with 6.57% respectively. Besides government has target of reducing biomass usage from 79.9% in 2020 to 42% in 2024 (MININFRA, 2021).

The partnership between Rwanda through REG and USAID of financial sponsorship of clean energy through power Africa being strengthened to provide sustainable development (Jean De Dieu Niyonteze et al, 2019). In addition; the policies related to the use of green and clean energy in transport like the use Electrical motor-cycle and electrical motor vehicles have been promoted and implemented by Rwanda government. The reasons for these policies are to reduce GHG emissions, Carbon emissions included. In fact, GHG emissions lead to the change in climate, which are the fearful problems faced by countries at highest level. The main cause of change in climate is the emission of CO_2 (which is dangerous among other GHGs) from different economic sectors. High awareness of CO_2 in atmosphere cause global warming and it is the main source of drought which may lead to hunger in different countries especially under developed countries.

The use of energy especially fossil fuel and charcoal burning and use of firewood in various economic sectors like transport, domestic use and cement production respectively, contributes to the emission of carbon dioxide emissions in Rwanda. Increasing GDP per capita was found to reduce CO_2 emissions by 1.45%, while 1% increases in industrialization increases carbon dioxide emissions by 1.64% in the long term (Samuel A. et al., 2017).

The charging moto-cycles and moto-vehicles are being encouraged by Rwandan institution in charge of environmental sustainability and conservations known as REMA under MINIRENA, it's one of the solutions for reducing GHG emissions in Rwanda. Apart from this policy they are other policies which helps to reduce Carbon dioxide emissions such as LPG (cooking gas) promoted since 2007, in addition Rwanda in partnership with international donors has started a policy known as National Domestic Biogas Program (NDBP) to reduce fire wood and charcoal for domestic use. apart from reducing deforestation other reason was to reduce CO_2 emissions by residential use (Matthew L. et Al., 2013).

One of the big problems faced by the world is the concentration of carbon dioxide in atmosphere. Due to too much concentration of CO_2 in atmosphere, various ways of reducing and mitigating the increase of its emissions has been revised as indicated by various policies and visions taken at both country and international level. As mentioned before Rwanda has different policies which are being used to mitigate CO_2 emissions such as emphasis on the use of green energy motor cycle and cars which use electricity (battery) as a form of fuel.

In 2015, Residential sector represented by 27% of world energy usage and carbon emissions were 17%, this is the fact that there is a noticeable role to reduce climate change (Ayam Nejat et all., 2015). In the implementation of Paris agreement, among 36 high-income countries in the agreement, 25 registered a decrease in their emissions in 2016-2019 compared to 2011-2015, including the United States with an average annual decrease of 0.7%, the European Union with an average annual decrease of 0.9%, and the United Kingdom with mean annual decrease 3.6. In 99 upper-middle income countries in the agreement, 30 countries also saw a decrease in their emissions in 2016-2019 compared to 2011-2015, suggesting that many countries around the

world are taking steps to reduce emissions. Mexico, with an average annual fall of 1.3%, is a notable example in this group; on the other hand, China's emissions increased by 0.4%, much less than the 6.2% annual growth of 2011-2015. (Stanford University, 2021).

Different scientific publications have been concerned with different ways of controlling and reducing CO_2 emission in atmosphere since 1970s. The crosscutting solution is the afforestation and energy crops that are able to save CO_2 (Ntanos S. et al, 2015) and use energy which are environmental friendly like P-V system and Wind Energy has been enforced as the long run solutions.

1.2. Problem statement

Normally, harmful C02 dioxide emissions results from use of hydro-carbon deposit in different forms through energy production or energy consumption. Main fossil-fuels include coal, natural gas, oil etc. Fossil fuel is mainly used in the following areas such as electricity generation, transport sector, industry, residential and agriculture sectors. In Rwanda the main origin of CO_2 emissions are Fossil fuels used in transport activities; however they are used by various industrial sectors as backup for any electricity dropout. The use of charcoal and wood burning by residential and cement production also emit too much CO_2 at high rate.

This research will provide fruitful results on the effect of energy usage in Rwanda to emissions of carbon Dioxide, by focusing on the CO_2 emitted from Oil usage, CO_2 emitted from cement production and Income (GDP) in Rwanda. Basing on this, the main questions to be answered in this research are “does energy consumption affects the emissions of Carbon Dioxide? Can carbon emissions be affected by GDP?

1.3. Objectives

1.3.1. Main objective

The main objective of the research is to analyze the effects of energy use in Rwanda on carbon emissions in atmosphere.

1.3.2. Specific objectives

-To identify the causal relationship between energy consumption and CO_2 emissions in Rwanda.

-To identify the causal relationship between gross domestic product and CO_2 emissions in Rwanda.

1.4. Scope of the study

The study focused primarily on assessing the impact of energy use on CO_2 emissions in Rwanda. Its aim is to identify the causal relationship between energy consumption, gross domestic product and CO_2 emissions. This study conducted by using data available on the WDI website, covering 29 years from 1990 to 2019. The analysis is done by using model known as VECM (Vector Error Correction Model) discussed in Chapter Three.

1.5. Expected outcomes and significant of the study

1.5.1. Expected outcomes

1. Energy consumption in Rwanda leads to the rise in CO_2 emissions.

2. The increase in gross domestic product is linked to the rise in CO_2 emissions in Rwanda.

3. There are good measures for improving the reduction of carbon emissions.

1.5.2. Significance of the study

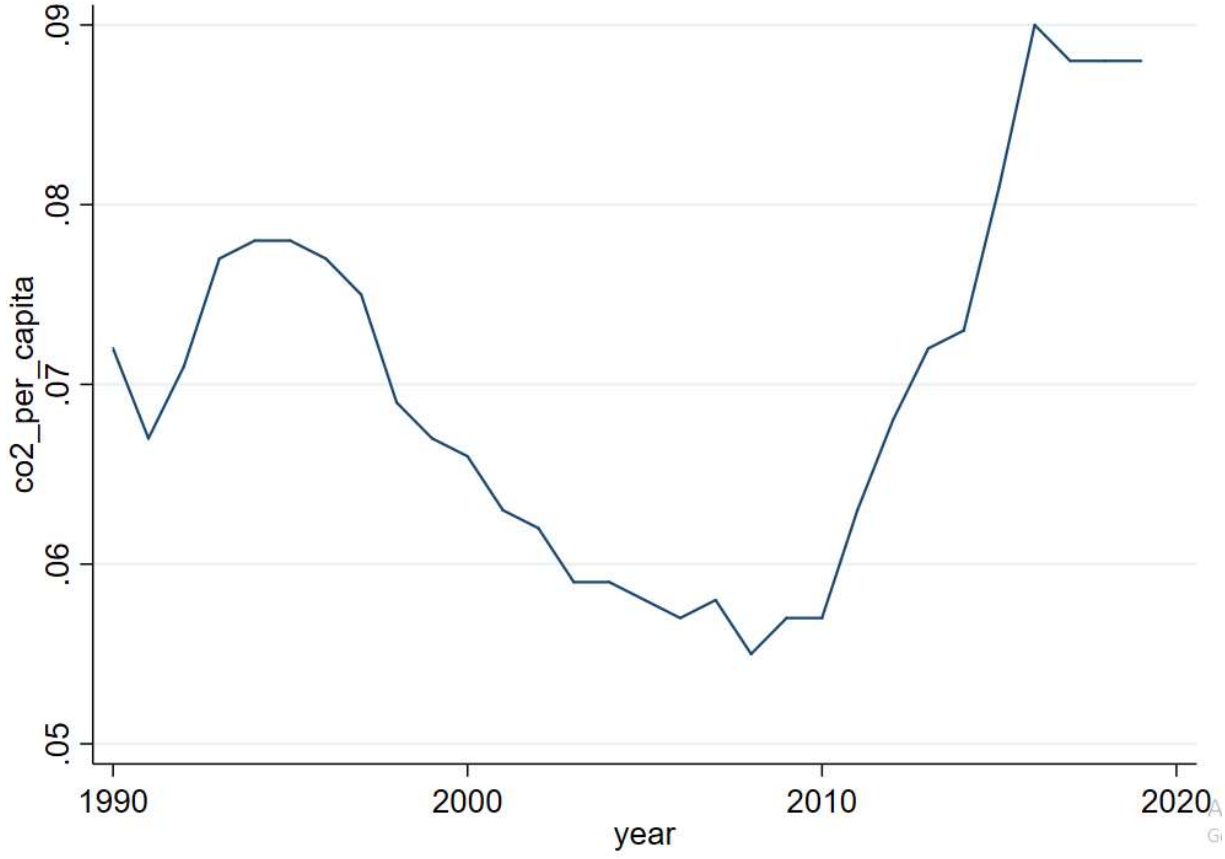
The results will be of important for society considering that carbon emissions affects various social economic activities and use of harmful energy can be direct cause Carbon emissions, the results will show the extent at which carbon emissions related to energy usage. For the researcher's perspectives, the study will contributes towards additional skills and knowledge on the research variable and their estimations. Moreover the completion of the study will allow the researcher to get master's degree in energy economics. For the university, the study is significant

because the copy of this thesis will be available in campus Library for the future readers and research will use this copy as reference.

CHAPTER TWO: LITERATURE REVIEW

2.1. Carbon Dioxide Emissions case of Rwanda

CO_2 is one of the natural greenhouse gases in small amounts, harmless, but if it increases, it can affect productivity (Airthings, 2021). Carbon dioxide released into atmosphere from different sources; natural sources are through respiration of animals. Another sources are fossil fuels, burning of crude oil, fire wood and other sources not mentioned.



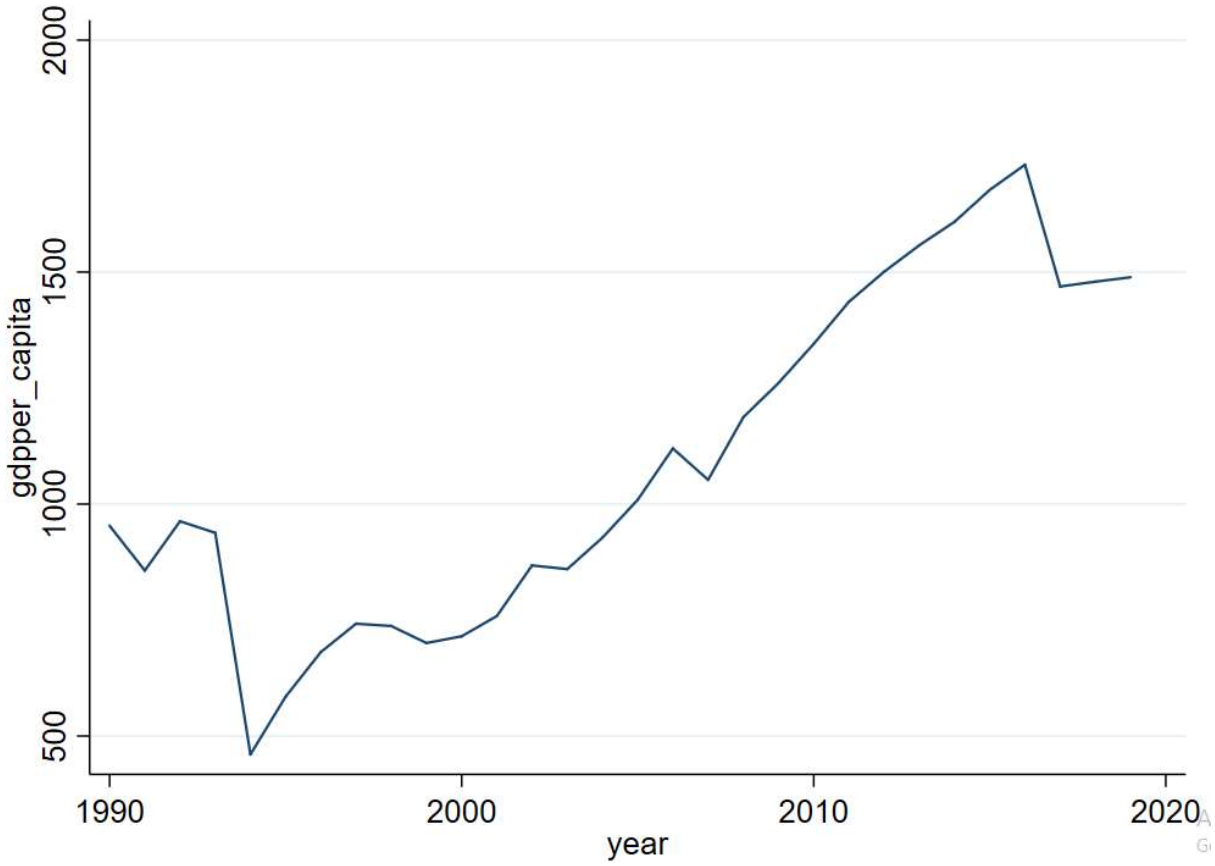
Graph 1: Total Carbon Emissions Rwanda (1990-2019)

This Graph 1 is explained in three phase, the first phase start from 1992up to the early 1994 there was an increase in carbon emissions which was followed by the second of the fall in carbon

emissions from the mid 1994 to 2010. Third phase start from 2010 to present which is dominated by steep rise in carbon emissions.

2.2. Gross Domestic Product (GDP) In Rwanda

GDP refers to the value of goods and services produced within a country during a given period of time. As a complete measure of all national production, it acts as complete catalog of economic health of corresponding country. GDP per capita is a measure of GDP per person in the population of precise country (investopedia, 2021). The 1994 genocide, which clearly marked a major turning point in the Rwanda's modern historical and development route, had a significant impact on its population. Since then, Rwanda's leadership has surrounded itself with celebrity international consultants to help shape the country's development and economic growth plan; Rwanda has developed Vision 2020 and other vision like VUP, Girinka program, These are the essential measures for development about a country (Maddalena C.et all, 2016). The Rwandan economy plummeted to 50% of its previous year's size in 1994, according to GDP (Maddalena C.et all, 2016) these shifts are shown on the next graph. Rwanda's GDP would not reach pre-genocide levels until the year 2000 (IMF, 2000).



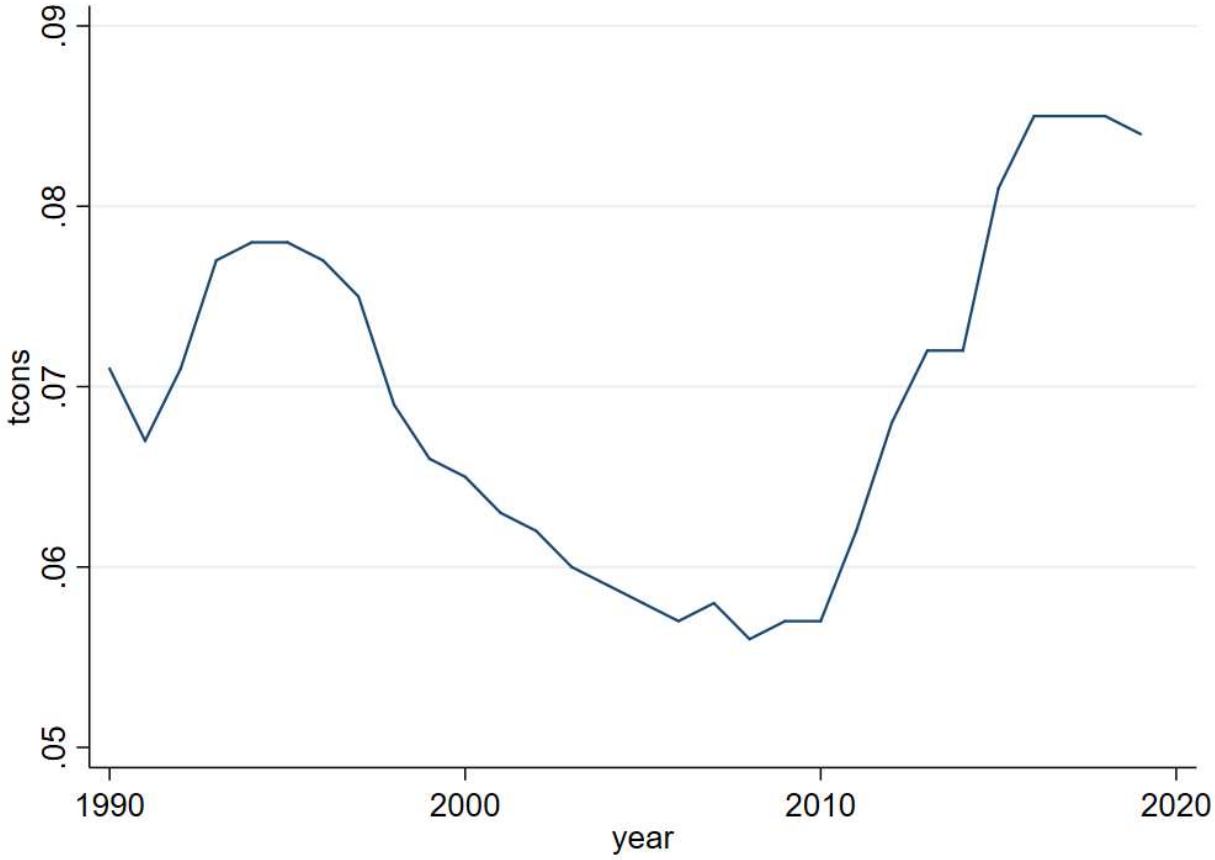
Graph 2: GDP per Capita of Rwanda (1990-2019)

The analysis in Figure 2 is explained into two parts, first part covers a period from 1990 to 1994 (Before Genocide against Tusti in 1994) where GDP per capita was decreasing until 1994 where GDP per capita were almost at 0, after 1994 to present GDP per capita rises at a higher rate yearly.

2.3. Energy consumption in Rwanda

Energy consumption defined as total energy produced and used by human being; also it may be defined as all forms of energy used to perform actions and manufacturing something. Rwanda is equipped with various energy resources like solar energy, biomass to mention but few. According to research (USENGIMANA J. D. et all., 2016) (MININFRA, 2021). Currently,

electricity supply In Rwanda generated mainly from hydroelectric together with thermal sources. Referring to MININFRA, the installed capacity was 218 mw in July 2018, with a capacity of 212.5 MW in country together with 5.5 MW as an import alternative, the country is well-equipped. This capacity includes hydro, with about 45 percent of installed capacity, diesel, which accounts for 27 percent, methane gas, which accounts for 14 percent, peat, which accounts for 7%, and solar, which accounts for 6%. Rwanda have much of domestic energy resources, however the vast majority of them are yet undeveloped (MININFRA, 2021).



Graph 3: Total Energy Consumption Rwanda (1990-2019)

Graph1 is showing Energy consumption per capita of Rwanda from 1990 up to 1992 there was a decrease in Energy consumption which was followed by the rise in energy consumption between 1992 to the early 1994, from mid 1994 to around 2008 there was a tremendous fall in energy

usage more precisely energy used in transport and cement production as they are the main target in the study, this was due to genocide Against Tutsi 1994 which followed by building the fallen country in different corners of development. This era was followed by steep rising of energy used in transport and cement production from 2008 present. This steep increase in energy consumption caused by the growth of transport and cement production sector as one of the indicators of development.

2.4. Review of the related studies in Rwanda

Rwanda located on African continent, Middle East, it covers 26,338Square Kilometers. Its population is around 12 Million people; per capita GDP was 904.70 USD in 2019 which was equivalent to 7 % of world's per capita GDP (Trading Economics, 2021). Rwandan government set measures for transmission towards transforming Rwanda from developing country into middle income country.

Rwandan government targeting 100% have electricity by 2024 (USAID, 2020); This is achieved through the national policy approach for electricity generation, which states that 52% population, will be connected through network expansion, while 48% of people linked to off-grid, only 14% out of the network (MININFRA, 2021).

Energy sector in Rwanda is not only reliable on Electricity but also includes Wood fuel, Charcoal, Biogas, other forms of petroleum products and Natural gas such as Methane gas (USENGIMANA J. D. et all., 2016). Rwanda total primary energy consumption of about 85% are from Biomass, petroleum products (Transport, electricity generation and industrial use) covers 11%, And 4% from hydro-power (MININFRA, 2021).

Carbon emissions rise by 2.88% in 2016 above the past year, which is equivalent to 39,234 tons 2015, when CO_2 Emissions is 1,363,854 tons (worldometer, 2020). The highest Carbon emissions sectors in Rwanda are transport with 55.3%, Power industry with 16.2%, Industrial combustion with 12.6%, building with 8.3%, and Non-combustion with 7.6% (worldometer, 2020). Researchers have shown that carbon emissions, GDP per capita, industrialization, and

population are cointegrated and have a long-term equilibrium relationship. (Samuel A. et Al., 2017). This research found that increased economic growth in Rwanda will reduce pollution in the long run to support the validity of the environmental Kuznets curve.

Study to assess a climate-resilient, low-carbon electricity supply scenario for Rwanda was done, analyzing financial and estimation of alternative clean energy to harmful energy, by taking into consideration Rwamagana Solar Energy power plant; This study concluded that the low carbon energy source developed is resilient as it meets projected needs when change in climate are taken into account. In addition, it assures security to the country's electricity supply since it depends on domestic energy resources (Theoneste U. , 2018). It was found that use of scenario in the study reduces carbon emissions by 40% lower than the emissions under BAU (Business as Usual) scenario (Theoneste U. , 2018).

2.5. Review of the related studies at global level

Many researchers have been working on consumption of energy and its effect on surroundings across the world. In Turkey, research found that Turkey should develop new policies to reduce environmental Deterioration (Halicioglu, 2009). CO_2 emissions can be determined taking into account the contribution of energy usage, GDP and international trade. (Halicioglu, 2009), many researchers have been using this relationship to analyze this relationship in developed countries (Halicioglu, 2009).

In the past research analysed Renewable energy as input to reduction in C02 emissions, it was found that income, renewable energies and Foreign direct investment are statistically significant to carbon emissions; in addition, CO_2 emissions decrease with the rise of clean and green energy consumption (Alex O.et Al., 2019). On the other hand, it was found that in low-income countries renewable energy are insignificant to CO_2 emissions. Differently, in high income countries renewable energy is highly significantly on CO_2 emissions (Alex O. et All., 2019).

Different researchers indicated that it is possible to predict the CO_2 levels basing on the past levels by using Engel and Granger causality test for test using variables like CO_2 emissions,

Energy consumption and Gross Domestic Product (Halicioglu, 2009). CO_2 emissions can be the results of population changes of any country, GDP and everyday's population activities while carbon intensity and energy intensity effects participate in reduction of emissions (Muhammad Y. R.et Al., 2019). Rwanda is fighting against greenhouse gases emissions by shifting from harmful energy to green and clean energy (REMA, 2021). According to REMA greenhouse gases emissions has been dominated by four main sectors covers 91% of total emissions, Agriculture soils emitted N2O at 57%, Enteric fermentation in domestic livestock emitted 19% of CH4 and 8% emitted CH4 from residential energy from fuel burning and lastly 5% of CO_2 were emitted from road vehicles (MINIRENA, 2011).

At global view GDP can affects the level of harmful gas emitted in atmosphere, it was shown by different research who proved the relationship between pollution and income, this was shown by the empirical results shows that there are constant with EKC hypothesis (Cropper, M., Griffiths, C., 1994), (Hettige, H. et Al., 1992), (Selden, T.M., Song, D., 1994), (Grossman, G.M., Krueger, A.B., 1995), (Martinez-Zarzoso, I., Bengochea-Morancho, A., 2004).

2.6. Empirical Review

The branch of literature that focuses on the tie between CO_2 emissions and international trade takes into account that, Environmental pollution occurs during the production of goods and is related to energy consumption in the country and, therefore, to the intensity of an economy's foreign trade may have a significant impact on pollution (Acaravci, 2013).

As a result, a lot of researches determine link arisen because of pollution and income. The EKC hypothesis is supported by empirical findings from (Hettige, H. et Al., 1992), (Cropper, M., Griffiths, C., 1994), (Selden, T.M., Song, D., 1994), (Grossman, G.M., Krueger, A.B., 1995), and (Martinez-Zarzoso, I., Bengochea-Morancho, A., 2004). Higher national GDP, beside, does not always imply more efforts to reduce pollution emissions. According to the empirical findings of (Holtz-Eakin D. et Al., 1992) and (Shafik N., 1994), pollution emissions increase monotonically alongside income levels. Since energy use has direct effect on the level of pollution, these discussions emphasize the need to combine these two lines of research. (Shafik

N., 1994) and (Holtz-Eakin D. et Al., 1992), Many scholars, including (Frankel J. et al., 1999), (S. Dasgupta et All., 2001), (Sadorsky P., 2010), (Zhang J., 2011), They have examined the influence of financial improvement on CO_2 emissions and have argued that it increases CO_2 emissions.

Financial development, According to these studies, it leads to a rise of CO_2 emissions because: first, the improvement stock market supports listed companies in reducing costs, expanding financing means, the diffusion of operational risks and the optimization of asset and liability structures to enable new investments to buy and get involved in new businesses, thereby increasing usage of Energy along with CO_2 emissions.

Second, fiscal development may encourage fexternal direct investment, resulting in increased economic improvement along with CO_2 emissions. Third, successful and effective financial intermediation appears to be favorable to consumer loan activities, making it simpler for consumers to purchase large-ticket items such as Cars, houses and fridge etc. which leads to increased CO_2 emissions (Zhang J., 2011). Differently, financial progress can increase energy efficiency also CO_2 emissions (Tamazian A., 2009).

The following are some recent studies analysed influence about financial development to CO_2 emissions. (Tamazian A., 2009) Examine the tie between economic growths along with environmental aspect in the BRIC countries, concluding that financial improvement act as critical component in reducing carbon emissions. In Turkey, long-term and causative links between CO_2 emissions, per capita energy usage, per capita real income, per capita income, openness, and financial development were examined in two steps.

To begin, the researchers used ARDL bounds testing methodology of cointegration assessing long term correlations of variables. Second, researchers used error correction model based on causality methods of testing the causal links. Financial development appears to have a short-run unidirectional causal link with per capita energy usage, per capita real income, and the square of per capita real income. In short term, a recovery in the financial sector will also lead to the rise in

energy usage and income. Turkey's financial progress leads to significance influence for country's increased energy consumption and income (Acaravci, 2013).

Nasreen S.et Al. (2014) examined causal relationship among openness to trade, economic growth along with energy usage. Using panel-integration and causality tests, the study found that there is a long-term bi-directional correlation between GPD, trade together with energy consumption in 15 Asian nations (1980-2011). The EKC scenario was included in the study as the aspects to consider when working on energy usage together with CO_2 emissions in these 15 countries (Nasreen S., 2014).

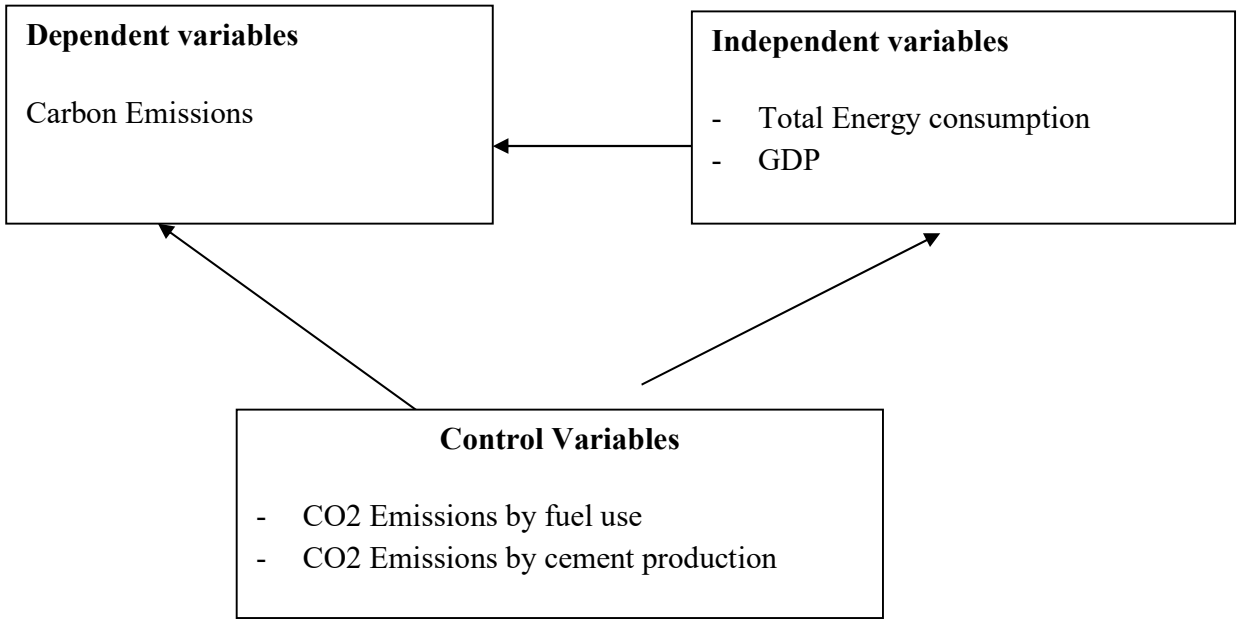
It was found that increased income along with trade boost energy consumption, increase in oil price, with exemption of a few select countries, reduces energy use. Based on 69 nations, Jebli et all. (2015) conducted research on international commerce, energy usage (1980-2010). The findings of from Granger test, existence of one-way relationship among the use of renewable energy together with trade for short-term, 0n other hand in long term, bidirectional relationship between these parameters present (Jebli M. B., 2015).

2.7. Theoretical framework

Globally, CO_2 emissions results from natural emissions caused by the exchange of CO_2 from the ocean along with atmosphere (Earth Hero, 2021), apart from this, the carbon emissions results from the energy uses from different sectors, i.e. industries, transport and domestic use. Various authors have done more research about carbon emissions and their sources (Alex O.et Al., 2019) (Acaravci, 2013) and (Ferda H., 2009) to mention but few. In this study, the emphasis is made on the analysis of the effects of energy usage to CO_2 emissions emphasizing on energy used in transport and cement production as the most sources of CO_2 emissions in Rwanda. Complementary Total output of Rwanda is taken as the control variable.

2.8. Conceptual framework

Below is the figure which indicates important variables in the study basing on the researcher perception vis-avis the objectives of the study. The conceptual framework is mainly made by the list of both independent, dependent and control variables related to the study.



Source: Researcher's Perception, 2021

Graph 4: Conceptual framework

Dependent variable is Carbon emission which is highly depend on use of energy and total output (GDP). The main origin of energy use in Rwanda are petroleum products (fuel) mostly in transport and industries and the cement production; this is the reason why CO_2 emissions by fuel use and CO_2 emissions by cement production are mentioned as control variables.

CHAPTER THREE: METHODOLOGY

3.1. Source of the data

This study analyses the effects of energy consumption to carbon emissions, the data used covers a period range from 1990 to 2019 extracted from a database of world development indicators (WDI). WDI is a set of development signs (Indicators) across the world identified worldwide sources, provided by the World Bank. This data set shows the most correct and actual world's development information nationally, regionally and globally. They was treated using a complete, integrated statistical software know as STATA15 and analysed using stationarity and cointegration tests and the Error correction model; which are more appropriate methods for analyzing the effects of energy consumption to carbon emissions.

3.2. Model specification

3.2.1. Variable specification

The analysis used the VECM model (Vector Error Correction Model) for studying the Effects of Energy usage to CO_2 Emissions in Rwanda. The choice of this VECM model is based on past researches that adopted the same approach for this kind of analysis (Ilhan Ozturk and Ali Acaravci, 2010) (Ferda H., 2009) (Benjamin S. et Al., 1997) (James, 2007) (Nicolas Apergis and James e. Payne, 2009) and (Graham E. et all., 1992), (Johansen, S., 1988), (James, 2007) and (Nicholas Apergis et Al., 2009). Our focus is the causal relationship between three variables of interest which are CO_2 emissions per capita as dependent variable and two independent variables which are total energy consumption per capital and GDP per capita. For great accuracy of the findings and goodness of fit of the model GDP per capita was transformed into GDP per capita squared. The following abbreviations were used:

- C_t stands for logarithm of CO_2 emissions Per capita at time t,
- E_t stands for logarithm of energy consumption per capita at time t,
- Y_t^2 is logarithm of per capita Gross Domestic Product squared at time t

The variables were transformed in natural logarithms to reduce problem of heteroskedasticity the model is specified as follows:

$$C_t = f(Ct, Et\ and\ {Y_t}^2) \quad (1)$$

The equation in structural form can be written as follow:

$$C_t = \alpha_0 + \alpha_1 E_t + \alpha_2 {Y_t}^2 + \mu_t \quad (2)$$

3.2.2. Data description

The main components of energy consumption are the energy used in transport and cement production in Rwanda. Variable of interest are presented in their natural logarithms for better interpretations and clear interpretations of the results.

The coefficients $\alpha_1 and\ \alpha_2$ Constitute the long run elasticity of CO_2 emissions per capita to energy consumption per capita, GDP per capita squared respectively. Data used were retrieved from World Development index for a period of 1990 to 2019 (WDI, 2021).

VEC model were used to test for causal relation of different variables referring to how other researchers in energy related researches used the VEC model various advantages which makes it more suitable for the research to test causality effects, these advantages are: The estimates from VEC Model are flexible and less demanding in terms of information and time and it allows the easy integration of new data. VECM (Vector error correction model) is appropriate method of the vector autoregressive model for stationary variables in their difference of order one.

3.2.2. Steps to be followed in VECM

First step: Stationarity test

The first step performed in VECM and VARM is an integration analysis using unit roots to check for serial data stationarity, if a shift in time does not bring about a shift in the shape of a time series, it is stated to be stationeries (Christopher F., 2009). To proceed with cointegration

checking stationarity test has to be tested (Christopher F., 2009). Unity roots Test used in the study to check for stationarity is ADF test. This test help to identify whether the series used are stationary or are non-stationary.

Mathematical representation of stationality test of the model:

$$Ct = \rho C_{t-1} + \sum_{j=1}^{k} \varphi_j DC_{j,t-i} + \mu t \qquad -1 \leq \rho \leq 1 \tag{3}$$

Where DC stands for determinants of Carbon emissions (C_t), which includes Energy usage (E_t) and GDP per capita squared (Y_t^2). Estimation of equation (3) is done using ADF test for stationarity, the null hypothesis (Ho) is denoted as Ho: $|\rho| = 1$ contrary to alternative hypothesis of $|\rho| < 1$. In case Null hypothesis is accepted i.e. the series is non-stationary, otherwise it is stationary (Niyitanga F., 2016).

Second step: Cointegration test of variables

The second step used is to check for cointegration. Cointegration tests find out degree where two or more non-stationary series are integrated in hence they cannot diverge from equilibrium over time. For cointegration to be performed the variables need to be stationary as proved in first step, this is to mean that only those which are stationary allowed to proceed with cointegration tests to find the equations which are cointegrated. By using johanse,s approach for each variables constructed levels (Cheung and Lai, 1993) cointegrating equations are obtained. This method is fulfilled by augmented dickey-fuller test (James, 2007) and (Benjamin S. et Al., 1997). The cointegration outh to be among the variables withinside the model: $C_t = \alpha_0 + \alpha_1 E_t + \alpha_2 {Y_t}^2 + \mu_t$

This estimations show the residual terms which is obtained from the equation of: $\mu_t = C_t - (\alpha_0 + \alpha_1 E_t + \alpha_2 {Y_t}^2)$ This must be stationary to allow the acceptance of the cointegration relationship of the variables (Niyitanga F., 2016).

Third step: test for causality using Error correction model

the third step of testing for causality proceed by performing Engle and granger test, these cointegrated variable have EC illustration wherein which an error correction term cited within the model, this fulfill conditions for testing causal as it is stated by (James, 2007) (Nicolas Apergis and James e. Payne, 2009). The following are mathematical representation of error correction model estimated. More details are discussed in the next chapter.

$$\Delta C_t = \beta_1 + \beta_{11} e_{t-1} + \sum_{i=1}^{d} \gamma_{1i} \Delta C_{t-i} + \sum_{i=1}^{d} \delta_{1i} E_{t-i} + \sum_{i=1}^{d} \tau_{1i} \Delta {Y^2}_{t-1} + \varepsilon_{1t} \quad (4.1)$$

$$\Delta E_t = \beta_2 + \beta_{21} e_{t-1} + \sum_{i=1}^{d} \gamma_{2i} \Delta C_{t-i} + \sum_{i=1}^{d} \delta_{2i} E_{t-i} + \sum_{i=1}^{d} \tau_{2i} \Delta {Y^2}_{t-1} + \varepsilon_{2t} \quad (4.2)$$

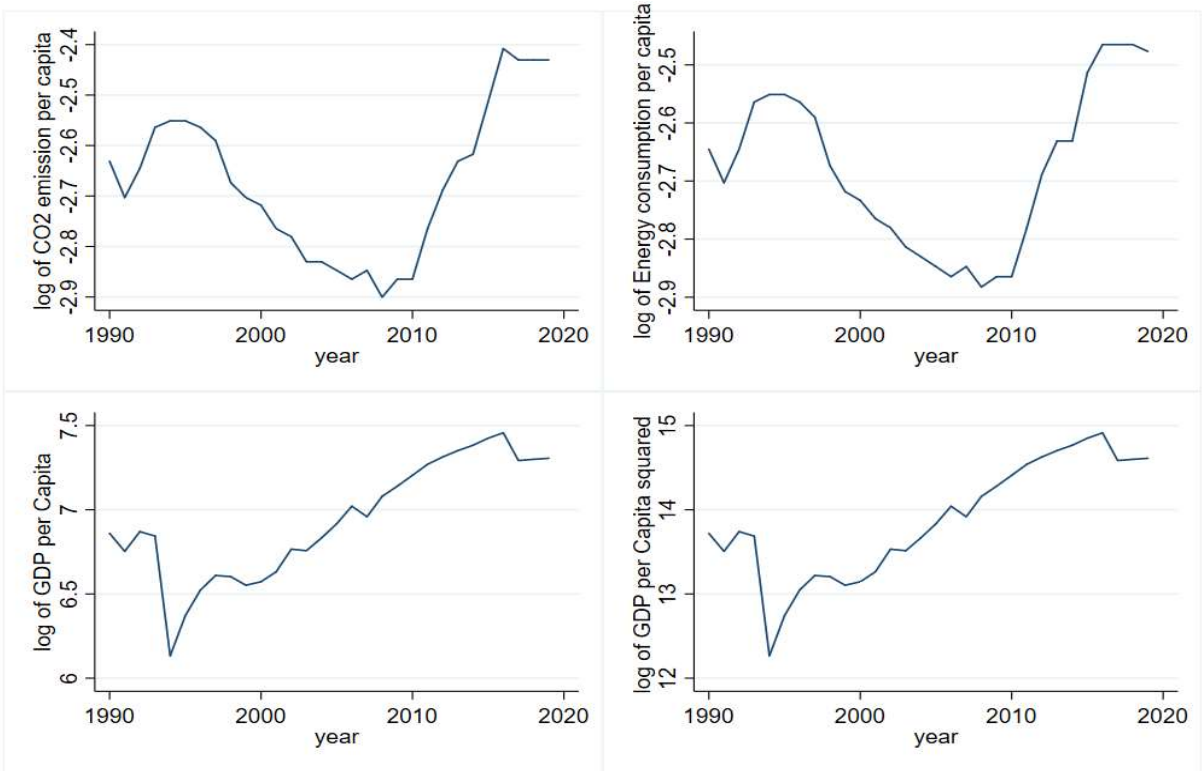
$$\Delta {Y^2}_t = \beta_4 + \beta_{41} e_{t-1} + \sum_{i=1}^{d} \gamma_{4i} \Delta C_{t-i} + \sum_{i=1}^{d} \delta_{4i} E_{t-i} + \sum_{i=1}^{d} \tau_{4i} \Delta {Y^2}_{t-1} + \varepsilon_{4t} \quad (4.3)$$

Where e_{t-1} represent error correction term in the model. Sources of causality are two: first is long run causation which is caused by error correction term, if $\beta \neq 0$. The second is short term causation which is the lagged dynamic term. The coefficient β which is an error correction tool must be significantly negative. Otherwise, the ECM specification must be rejected because the error correction term would move in the opposite direction and would move away from the long-term relationship (Niyitanga F., 2016).

CHAPTER FOUR: FINDINGS OF THE STUDY

4.1. Trend analysis: Graphical presentation of CO_2 emissions, energy consumption and GDP

As it is shown on the figure 5 there is changes for Carbon dioxide emissions and energy consumption where by there is a steep trend decreases from 1990 to 1991 then after there is a trend increases from 1991 to 1993. Between 1994 to 2010 there was a trend decrease for both variables. From 20210 to present there is an strict trend increase for Carbon Emissions and Energy consumption. Differently, the changes on trend of GDP can be divided into two parts: from 1990 to 1994 there was a strict decrease in country output from 1994 to present there is a perfect increase in gdp.



Source: Study findngs by STATA.

Graph 5: Trend Comparison of CO_2 emissions, energy consumption and GDP in Rwanda

4.2. Analysis of the relationship between CO_2 emissions and energy consumption and GDP

4.2.1. Unit root test

Two methods were used to test unit root test namely ADF test and P-Philip test. It is recommended to analyse the stationarity of times series and make them stationary if they are not stationary before proceeding to estimation. In this research it was found that after first difference all variables become stationary as it is shown in table 1.

Table 1 showing unit root tests results

Variable Name	dfuller_statistic	dfuller_cvalue	dfuller_pvalue	dfuller_lags	pperron_statistic	pperron_rho	pperron_pvalue	pperron_lags
C_t	-3.66	-2.99	0	0	-3.81	-20.74	0	3
E_t	-3.3	-2.99	0.02	0	-3.45	-18.01	0.01	3
Y_t	-5.64	-3	0	0	-5.76	-26.33	0	2
Y_t^2	-5.64	-3	0	0	-5.76	-26.33	0	2

Source: Researcher's finding by using STATA

By looking at the results of first difference of dfuller test in table 3 and table 4, statistical value of C_t, E_t, GDPt and GDPtsqr in absolute value are 3.66, 3.30, 5.64 and 5.64 are greater than critical values by ignoring negative signs of 2.99, 2.99, 3.00 and 3.00 for significance level 1%, 5% and 10% respectively. This dictates to accept Alternative hypothesis that C_t, E_t, GDPt and GDPtsqr variables don't have unit root. Else ways, the first difference Philip Peron test was conducted, the results obtained for statistical value are 3.81, 3.45, 5.76 and 5.76 are much greater than critical values for the variables C_t, E_t, GDPt and GDPtsqr respectively. In fact, for both dfuller and PPerron tests for unit root; Carbon emission (C_t), Energy consumption (E_t), Gross domestic product (GDPt) and Gross domestic product squared (GDPtsqr) are stationary i.e. they reflect the true values not depending on time variant.

4.3. Cointegration test

$$C_t = \alpha_0 + \alpha_1 E_t + \alpha_3 {Y_t}^2 + \mu_t \quad (5)$$

To obtain cointegration results, vecrank stata code were used to generate statistics showing the number of cointegration equations in VEC Model for causal relation analysis (StataCorp LLC, 2017). The outputs are presented in table 6.

Table 2 Johansen tests for cointegration (trace statistics)

Trend: constant				Number of obs = 26	
Sample: 1994-2019					Lags = 4
Max				Trace	Critical
Rank	Parms	LL	eigenvalue	Statistic	value (5%)
0	30	124.56	.	63.68	29.68
1	35	145.76	0.8	21.28	15.41
2	38	154.92	0.5	2.95*	3.76
3	39	156.4	0.1		

Source: Researcher's finding by using STATA

Table 2 represents statistics which helps to find level of cointegration in vector VEC Model by considering trace statistics. At rank equals to 0 trace statistics is 63.68 greater than its critical value of 29.68, hence null hypothesis of no cointegrating equations is rejected. Thus, hypothesis that there is a presence of single cointegrating equation is rejected. This is to mean that the trace statistics at rank 1 is 21.28 greater than the critical value of 15.41. On the other hand, for rank equals to 2 trace statistics of 2.95* exceeds its critical value of 3.76; hence, hypothesis that there are two or fewer cointegrating equations are accepted. Thus, r = 2 is accepted as the estimation of the level of cointegrating equations between these three variables, in view that Johansen's mtechnique for ccomputing r is to accept the primarily r for which the null hypothesis is not rejected (Johansen, S., 1988) and (StataCorp LLC, 2017). The star on trace statistics at rank

equals to 2 indicates that Johansen's multiple trace test process, this value equals to maxim rank of two cointegrating equations.

4.4. Discussion of vector error correction model estimation results

VEC model uses Johansen's maximum likelihood method to fit a sort of VAR in which a number of variables are cointegrated (Johansen, S., 1995) and (StataCorp LLC, 2017). The coifficients within the cointegrating equations or the adjustment terms are both constrained. Representation of the results from regression made using STATA 15 are shown in table 3.

Table 3 showing VECM output

beta	Coef.	Std. Err.	Z	P>z	[95% Conf.	Interval]
Ct	1	.	.	.	.	.
Et	-1.07	0.02	-54.75	0	-1.11	-1.03
Y_t^2	-0.02	0	-4.36	0	-0.02	-0.01
_cons	0.06	.	.	0	.	.

Source: Researcher's finding by using STATA

After the above findings the Cointegrated equation became:

$$Ct = 0.06 + 1.07\text{Et} + 0.02\ Y_t^2 \quad (6)$$

By considering results presented in table 8 showing long run equations often called Johansen normalization restriction, the restriction was posted on log of carbon emissions (Ct) which is a target variable in the study. In long run, it was found that the rise in logarithm of Energy consumption (Et) and logarithm of GDP per capita squared (Y_t^2) leads to the rise of the Log of carbon emissions as shown in table 3. It implies that the increase of 1.07% of Energy consumed (in TJ) is associated with an increase of 1% of million tons of CO_2 emissions. In addition to that, the rise of 0.02% in Gross domestic Products is associated with 1% increase of metric tons of

carbon emitted in atmosphere as shown in table 3. For more clarification the value of coefficients -1.07 and -0.02 their signs have to be reversed (Johansen, S., 1995). The parameters are significant at 1%, 5% levels as shown by p-values (P>z).

In addition, the output in table 3 show that Et and Y_t^2 has symmetric effects on Ct in the long-run on average, ceteris paribus. The long-run elasticity of carbon emissions (Ct) in relation to Et is determined to be 1.07 million tons. The discovery suggesting that Et had a positive effects to Ct, which is in line with expected outcomes. Similarly, the long-run elasticity of Ct in relation to Y_t^2 (Gross domestic Product) is 0.02%.

The equations after getting results from VEC model, the equation for target variable Ct is as follows:

$$\Delta logC_t = .03 - 1.86e_{t-1} + 0.16\,\Delta logC_{t-i} + .02\,logE_{t-i} - 0.01\Delta logY^2{}_{t-1} \quad (7)$$

The estimated value of e_{t-1} (-1.86) is negative, with 5% and 10% significance level. These propose that a shift from long-term equilibrium is corrected in the present year, at a merging speed of 1.08%. Beside, the values of parameters $(0.16\,, 0.02\ and\ -0.01)$ in short-run, suggest that deviations from short-run equilibrium rise by 0.02% of Carbon emissions in previous year and 0.02% by Energy consumption while there is a fall in short-run equilibrium of 0.01% of GDP.

To make sure that the results presented in table 3 are Autocorrelated and stable, the tests for mentioned issues were conducted; table 4 and 5 show the results respectively.

Table 4 Autocorrelation test

Lagrange-multiplier			
Lag value	chi2 statistics	Dfuller	Prob > chi2
1	8	9	0.53
2	9.93	9	0.35

Source: Researcher's finding by using STATA

Table 5 Checking stability status

Eigen value	Modulus
1	1
1	1
0.58	0.58
-0.39	0.39
.028 + .029i	0.04
.028 - .029i	0.04

Source: Researcher's finding by using STATA

By reading the results in Table 4, null hypothesis that no autocorrelation exists in the disturbance for any of the orders investigated at the 5% level (StataCorp LLC, 2017). Since statistical values are greater than 5% significant level for all lags used in VECM cannot be reject. The results show no indication of model misspecification in this test. The companion matrix's Eigen values and their related moduli are listed in table 5. One of the roots is 1, as shown in table 5. VECM place a unit modulus on the associate matrix. According to the table footer (StataCorp LLC, 2017). The Eigen value results of 0.58 imply that there is a real root at 0.58, which is not very close to 1 which leads to conclude that the predicted cointegration equation is probably stable. The increase of 1% in energy usage leads to increase of 1.07% of CO_2 emissions. Thus,

confirms the causal relationship between Energy consumption and CO_2 emissions was identified. Differently, the Rise of 1% in GDP induces the rise 0.02% in CO_2 emissions as well. These results confirm that there is a clear causal relationship between the variables under the study.

CONCLUSION AND RECOMMENDATIONS

In this research, the connection among energy usage, GDP and CO_2 emissions in Rwanda in the period of 1990-2019 have been analyzed using VEC model. At the beginning the main problem leading to the conduction of this study was to find the cause of CO_2 emissions in Rwanda, based on current status of CO_2 emissions which is 0.08metric tons in 2020. The objective for the research is to investigate effects of energy usage in Rwanda on CO_2 emissions in atmosphere. Furthermore, other objective is analysis of causal relationship among GDP and CO_2 emissions. The VEC model for studying the Effects of Energy usage on CO_2 Emissions in Rwanda was employed.

Through the use of VECM, the results show that there is long-term correlation among the variables. It was found that the increase of 1.07% of Energy consumed (in TJ) is associated with an increase of 1% of million tons of CO_2 emissions. Findings confirm that more energy consumption (use) results in more CO_2 emissions. Complementally, the rise of 0.02% in Gross domestic Products is associated with 1% increase of metric tons of carbon emitted in atmosphere. However, in short-run analysis shows that energy consumption same as GDP cause Carbon emissions. These findings are obvious and expected given that the increase of Gross domestic product requires energy usage, some of the energies generate carbon dioxide emissions after all.

As recommendation, the researcher recommends the government to enforce policies related to the use of green energy in order to reduce the use of harmful energy such as fuel used in transport. Researcher propose that through the existence program of providing Moto vehicles and motor cycles to government institutions, government is advised to provide those which use green energies for better sensitization of the use of no harmful energies such as charged motor vehicles and motor cycles. In addition to this schools and other public place like prisons where many people gathers are advised to use liquidified petroleum gas for cooking to reduce CO_2 emissions from cooking. The reduction of emissions of CO_2 is not only the responsibility to the government but also to the society, people are recommended to reduce the use of oil fuelled

vehicles in favor of charged vehicles and motor cycles, this could be done through reduction of taxes for private imported which use green energy like cars and motor cycles.

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