ANALYSING THE RELATIONSHIP BETWEEN CARBON DIOXIDE EMISSIONS, RENEWABLE ENERGY UTILIZATION, AND ECONOMIC GROWTH IN KENYA

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DECLARATION

This Research project is my work and has not been submitted for any award in any other university.

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X50/12698/2018

This Research project has been submitted for examination with my approval as the university supervisor.

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DEDICATION

This Research study is dedicated to my family and Kenyans who work tirelessly to promote a low-carbon environment.

ACKNOWLEDGEMENT

It has taken God's grace and favor.

Prof Richard Mbithi Mulwa, my supervisor, deserves special thanks for his steadfast support and advice during this study. I appreciate my family's patience, love, and support during my academic career. May God continue to bless you.

I appreciate my friends and course mates for the guidance academically and emotionally throughout my study period.

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AIC	Akaike Information Criterion
ARDL	Autoregressive Distributed Lag Model
EKC	Environmental Kuznets Curve
CO_2	Carbon Dioxide Emissions
GDP	Gross Domestic Product
GESIP	Green Economy Strategy and Implementation Plan
EPA	Environmental Protection Agency
WHO	World Health Organization
NEMA	National Environment Management Authority
IEA	International Energy Agency
LR	Long Run
SR	Short Run

ABSTRACT

This study analyzes the relationship between Carbon Dioxide emissions, renewable energy utilization, and economic growth in Kenya for the period 1971 -2015 using the Auto Regressive Distributed Lag (ARDL) Model. The main objective of the study was to assess the relationship between carbon dioxide emissions, renewable energy utilization, and economic growth. There exists a positive association between carbon emissions and per capita GDP in Kenya which is significant. Renewable energy has a positive while urbanization has a negative but insignificant relationship with carbon emissions in the LR. The government can subsidize the energy sector to encourage the use of clean energy. Funding by both international and domestic donors towards green technology should be encouraged with such funding well accounted for. It can increase sensitization of people towards the green economy as the people lack adequate information on green technologies which would help in promoting a low carbon economy. The citizens would also be informed more on goods and services produced from green technologies as this would ensure that technology transfer is high promotion its adoption and adaptation. The government, therefore, can fund research and development on green technology as this would provide more information on the cost- benefit analysis of adopting the green technology in production process.

CHAPTER ONE: INTRODUCTION

1.1 Background of the study

1.1.1 Natural resources and the GDP

Natural resources[1] such as mineral and energy resources[2], water resources[3], biological resources[4] and soil resources[5] are significant in poverty reduction, enhancing fiscal revenue, and contributing to economies globally (United Nations- SEEA, 2003). Thus, they need proper management of these resources to contribute to short- and long-run revenue (OECD, 2011). Their exploitation globally has led to the doubling of the global Gross Domestic Product since 1970 (Global Resources Outlook, 2019). In developing countries, natural capital constitutes a larger percentage of a country's total wealth than the produced capital, and agricultural land covers a great percentage of the natural resources of the low-income countries (World Bank, 2005). In 2016, natural resources constituted 1.7% of the world GDP with oil rents constituting 0.8%, 0.1% for natural gas, 0.2%, for coal, 0.4% for minerals, while forests rents accounted for 0.2%. In low-income countries, natural resources rents accounted for 11.8% of the GDP in 2016, with forest rent being the greatest contributor accounting for 8.3%, 2.9% for minerals, 0.4% for oil, 0.1% from natural gas, and 0.1% from coal (World Bank, 2017).

The utilization of natural resources could result in a resource curse or create an opportunity for developing natural resource-rich countries (Stevens and Dietsche, 2008). Resource curse occurs when the utilization of resources results in poor development instead of poverty reduction and increasing development in the country. Prices for oil, minerals, gas and other natural resources are expected to increase in the revenues for the exporting countries and create development opportunities, yet this is not the case under the resource curse. Poor but resource-abundant economies utilize the gains from exporting natural resources in ways that benefit society in general

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[1] Natural resources refer to the elements of the environment that provide raw materials and energy that are used for economic consumption and production (United Nations -SEEA 2003, para 7.42).

[2] The mineral and energy resources are the sub-soil deposits of fossil fuels and both the metallic and the non-metallic minerals (ibid., para 7.43).

[3] Water resources refer to water found on the fresh, surface, and groundwater bodies within national territories (ibid., para 7.47).

[4] Biological resources consist of timber, plant, crop, and aquatic and animal resources other than marine resources (ibid., para 7.53).

[5] The soil resources consist of soil found on the agricultural land and anywhere within national territories of the globe (ibid., para 7.44).

and only benefit the elite. The result is poor authoritarian governance, increased conflicts, weak institutions, and inequitable distribution of natural resources rents. (NRGI Reader, 2015). Eventually, this overdependence on the natural resources to increase GDP results in adverse effects where overexploitation of the natural resources results in a decline in the GDP (Lampert, 2019).

1.1.2 Environmental Pollution

Pollution of the environment takes various forms, including air, water, and land pollution (Bradford, 2018). Air pollution occurs when particles from burning fuels, dangerous gases such as nitrous gases are released into the air, and greenhouse gases are released into the environment. Water pollution results from the disposal of chemicals such as fertilizers and pesticides, waste, e.g., sewerage, foreign objects, and other pollutants into water. Land pollution occurs when industrial and municipal waste is disposed of on land. Air pollution is the most significant pollution source, accounting for approximately 7 million deaths globally, with increased air pollutions exposure rates in low-income and middle-income economies (WHO, 2020). The deaths are due to both household and outdoor air pollution. Air pollution is also a great contributor to various diseases such as heart diseases, cancer, stroke, and asthma, among other respiratory disorders. The most significant air pollutant is Carbon dioxide which is responsible for causing climatic changes globally. Carbon dioxide is produced through fuel from planes, vehicles, burning of fossil fuel, e.g., natural gases and gasoline (Nunez, 2019). Globally, carbon dioxide has been on the rise, with low levels of emissions in the period before the industrial revolution reaching a total of 36.15 billion tonnes as of 2017 (Global Carbon Project, 2019). In 2017, Asia was the largest Carbon dioxide emitter accounting for approximately 53% of the global emissions, followed by North America, which accounted for 18%, Europe accounted for 17% of the global emissions. Africa accounted for 3.7%, South America 3.2 %, while Oceania accounted for 1.3% of the global emissions of Carbon dioxide (Ritchie, 2019).

Pollution into the atmosphere results in climate change with cooling or warming effects on the atmosphere (EPA, 2020). For instance, black carbon absorbs heat, resulting in increased atmosphere warming, while particulate matter such as sulphates has a cooling effect. Carbon dioxide is a worthy cause of the greenhouse gas effect, among other gases such as nitrous oxide, water vapor, chlorofluorocarbons, and methane, which cause climatic changes (NASA, 2020). Carbon dioxide emissions into the atmosphere have increased by nearly 40% since the period before the industrial revolution. Anthropogenic activities have increased carbon emissions into the atmosphere as humans aim to increase income and economic growth. The burning of coal, oil, and other fossil fuels increases greenhouse gas concentrations, leading to rising atmospheric temperatures. The increase in temperatures leads to precipitation and increased evaporation resulting in some areas receiving increased rainfall while others dry up, thus threatening global food security. The reduction of the particulate matter emissions into the atmosphere would result in health benefits by reducing respiratory diseases and improving the climate (European Commission, 2010).

An alternative to cutting down on air pollution is the use of clean energy. It would aid economies in reduction pollution and increase supply of electricity while positively affecting climate change (United Nations, 2018). To address the reduction of carbon emissions globally, the Paris Agreement was formulated in December 2015. The Paris Agreement necessitates the United Nations Convention on Climate Change members to take actions that would boost the activities and investment to the attainment of a low level of carbon to combat the changes in climatic conditions in the world as well as help developing countries in taking up the right policies (UNFCCC, 2015). The various issues addressed in the Paris Agreement to combat climate change include: keeping the temperatures below 2 degrees Celsius and increase in temperatures limited to 1.5 degrees Celsius; global peaking of greenhouse gas emission; each country to formulate its own intended nationally determined contribution (INDC); adaptation policy whereby economies reduce the vulnerability to climate change, among other issues. The Paris Agreement ensured that the developing countries were supported voluntarily by the developed countries in terms of finance, technology, and capacity building. Transparency and accountability, as well as public awareness and education on climate change, were encouraged. Despite the pledges made by countries under the Paris Agreement in reducing carbon dioxide emissions, this alone would not be enough to keep the levels of emission as low as possible (UNEP, 2017). The use of green technologies will ensure that clean energy is prioritized over nonrenewable energy sources, ensuring that carbon emissions are held to a minimum to meet the Paris Agreement’s objectives. The renewable energy sources used in generating electricity to reduce carbon dioxide emissions include wind, solar, biomass, geothermal and hydroelectric energy. Economies across the globe have increased their utilization of renewable energy as a way of decarbonization of energy which led to a global renewable energy utilization of 11% based on the worldwide energy share with hydropower accounting for the most significant percentage of the renewable energy from 1965 to 2019 (Ritchie, 2017). Thus, to reduce carbon emissions, economies need to increase renewable energy utilization without compromising economic growth.

1.1.3 Natural Resources and Environmental Pollution in Kenya

According to the World Bank, Kenya's GDP growth rate has been quite unstable with fluctuating growth rates. In 2019, the Growth rate was 5.366%, which declined from 6.3% achieved in 2018. The most significant sector contributing to the GDP growth in 2019 in Kenya was the service sector accounting for 43.2%, followed by agriculture, which accounted for 34.15%. Lastly, the industrial sector accounted for 16,15% of the GDP (Plecher, 2020). The total contribution of natural resources to Kenya's GDP in 2017 was 2.4% and 1.3% in 2018. These natural resources include oil, minerals, forests, coal, and natural gas, with the forest being the most significant contributor to the country's GDP accounting for 2.4% in 2017 and 1.3% over the same period. The second-largest contributor of GDP is mineral rent, accounting for 0.018% in 2017 and 0.006% in 2018.

Air pollution is the most significant in Kenya, especially outdoor air pollution (Ministry of Environment & Forestry, 2013). It ranks eighth as a risk factor for premature deaths accounting for approximately 19,000 deaths in the country, with 5000 cases due to ambient air pollution and14,000 from outdoor air pollution (State of Global Air, 2020). According to the report, Kenya's population lives in areas where the $PM_{2.5}$[6] exceeds the WHO guidelines of 10 μg/m3. Air pollution leads to respiratory, heart diseases, and cancer, among other conditions. Air pollution is most significant due to vehicle, industrial emissions, burning of charcoal, and municipal sources such as the open burning of garbage, among others (Nthusi, 2017). The typical gases emitted include Sulphur Oxide, Carbon Monoxide, Nitrogen Oxide, and particulate substances such as black carbon, released into the atmosphere.

In 2013, the CO_2 emissions totaled 60.2 million metric tons in Kenya, which accounted for 0.13% of the global greenhouse gases emission with the highest emission being from the agricultural sector, which accounted for 62.8% of the emissions, 31.2 % from the energy sector, the industrial

[6] $PM_{2.5}$ denotes particulate matter whose diameter is less than 2.5 and remain suspended in the air compared to other particulate matter (Airveda, 2017)

sector accounted for 4.6% with the lowest sector being the waste sector which contributed to 1.4% of the overall emissions (USAID, 2017).

Air pollution in Kenya is a great cause of climate change, leading to drought, floods, increased poverty levels, poor distribution of land, and other impacts of climate change (NEMA, 2020). Climate change remains a significant risk to sustainable development in the country. We should ensure that the effects associated with climate change do not reverse the progress so far made. The drivers of the Kenyan economy, including wildlife and tourism, agriculture, and forestry, are subject to changes in climatic conditions. Thus, the right policies that would reduce the level of pollution and climate change should be considered. For Kenya to comply with the set policies under the Paris Agreement, the country came up with various approaches to ensure that climate change is reduced to an agreed level to keep the temperatures below 2 degrees Celsius. The Ministry of Environment & Natural Resources (2015) formulated the INDC which discusses both the mitigation and adaptation plans which would enable the country to achieve low levels of carbon emissions. The mitigation plans include; expanding renewable sources of energy together with other clean energies with low carbon emissions, the use of clean technology to reduce the overreliance on wood for fuel, use of efficient transport systems with low carbon emissions and the use of sustainable waste management among other mitigation actions. The Government of Kenya (2015) implemented the Green Economic and Implementation Strategy (GESIP) in 2016 to help meet the set temperatures to prevent climate change. The GESIP was based upon five blocking blocs: promoting sustainable infrastructure, enhancing sustainable management of resources, building resilience, encouraging resource productivity and social involvement, and promoting sustainable livelihood.

The electricity demand in Kenya increased by 18.9% per annum between 2004 and 2013, exerting pressure on the existing electricity production capacity due to the country's increased economic growth (Mokveld and Eije, 2018). The government aims to reduce carbon dioxide emissions by improving the electricity supply using renewable energy. The country increased its use of hydropower and geothermal power to produce electricity to lower the electricity generation using fossil fuel, contributing to carbon emissions in the atmosphere. Electricity consumption is highly used by the industrial sector and residential sectors (IEA Statistics, 2015). Geothermal energy accounts for the most significant percentage of 46%, followed by hydro energy, which accounts for 39% of the electricity, while production with oil accounts for 12%. Kenya is fully endowed with renewable sources of energy and should use its advantage in electricity generation. For instance, according to the final energy report in 2018, Kenya is endowed with geothermal resources. It aims to convert into the production of geothermal power by 2030 to provide 5000MW of power. The government has high insolation rates averaging 5 to 7 peaks sunshine hours, which could be a great way of rural electrification using solar energy. Since the country depends upon agriculture in its economic growth, the agricultural wastes could be utilized efficiently in energy production, and wind power could be adequately and efficiently used to generate energy. Thus, the country needs to switch from nonrenewable sources of energy to renewable sources. Additionally, efficient utilization of renewable energy should be ensured. It will lessen the undesirable effects of climate change and spur the economy into achieving higher levels of the green economy.

1.2 Statement of the problem

The various human activities in Kenya are both great contributors of the carbon dioxide emission and GDP growth. The country in an aim to keep with the low levels of emission as per the Paris Agreement, formulated the Nationally Determined Contribution (INDC) that showed the mitigation and the adaptation plan that would help it in meeting the set objective as it purposes at decreasing the emissions by 30% by 2030 (Mokveld and Eije, 2018). The plan would help the country in achieving the low levels of carbon by increasing efficiency in the utilization of renewable energy, which would replace the usage of nonrenewable energy in the country, especially in the production of electricity as the country's objective is to have the country 100% electrified by 2022 (World Bank, 2018). Since carbon emissions and economic growth tend to follow the same path, low-carbon policies, such as dependence on renewable energy, would affect economic development. Therefore, the study investigates how economic growth and renewable energy influence carbon dioxide emissions and provides policy options to reduce carbon emissions through renewable energy adoption in ways that do not compromise economic growth in the country. The study, therefore, attempts to bridge the gap in the literature by investigating the relationship between carbon dioxide emission, renewable energy utilization, and economic growth in the country.

1.3 Research Questions

The following research questions will guide the study:

1. What is the influence of economic growth on Carbon dioxide emissions?
2. What is the influence of renewable energy on Carbon dioxide emissions?
3. What are the appropriate policy options that reduce Carbon dioxide emissions without compromising economic growth?

1.4 Objective of the study

The main objective of this study is to assess the relationship between carbon dioxide emissions, renewable energy utilization, and economic growth. It is operationalized in the following specific objectives;

1. To examine the influence of economic growth on Carbon dioxide emissions
2. To investigate the effect of renewable energy utilization on Carbon dioxide.
3. To recommend appropriate policy options that reduce Carbon dioxide emissions without compromising economic growth.

1.5 Significance of the study

The study will examine how economic growth and renewable energy utilization affect Kenya's carbon dioxide emissions. It will provide important information to the government, which will be helpful in policy formulation of attaining low carbon levels through utilizing renewable energy and ensuring that it does not compromise on economic growth. The study will also bridge the gap in the current literature regarding how Carbon dioxide emissions are affected by renewable energy and economic growth, which will be helpful in academia.

CHAPTER TWO: LITERATURE REVIEW

2.1 Chapter overview

Various theories that guide the study and other studies related to the subject area carried out by different scholars in different countries are discussed in depth. These studies provide background information to understand how carbon dioxide relates to renewable energy utilization and economic growth.

2.2 Theoretical Literature Review

The study has reviewed three theories: Environmental Kuznets Curve, Ecological Modernization Theory, and Inclusive Green Economic theory. Environmental Kuznets Curve describes how environmental degradation relates to per capita growth. Ecological Modernization theory discusses the use of clean technology to reduce environmental degradation. The Inclusive Green Economic theory aims to attain sustainable development through green technology such as renewable energy.

2.2.1 Environmental Kuznets Curves

Kuznets (1955) first explained how economic growth links with income inequality. He argued that income inequality increased at the earlier phases of industrialization until it peaked and declined as development of the economy was witnessed. Environmental degradation is high at the initial levels of development, accompanied by little focus on environmental quality. As economies develop, economic growth drives the economy towards a cleaner environment, and at this time, environmental degradation is seen to decline. This relationship witnessed at both the initial stages of development and at higher levels of growth depicts an inverted u-shaped kind of association. At the initial phases of industrialization, manufacturing industries predominated the sector as numerous activities were explored to increase the economy's GDP. As the economy progressed, manufacturing was replaced by moving towards the service sector with low emissions levels. Thus, the economy transformed to the industrial sector from the agricultural sector and finally became service-oriented, which accounted for the reduced levels of degradation of the environment.

His ideas were later adopted in environmental economics and led to the Environmental Kuznets Curve (EKC). Grossman and Krueger (1991) tested the presence of EKC, whereby they confirmed the inverted u-shaped relationship between economic growth and degradation of environment on NAFTA. They reasoned that reducing trade barriers would harm the environment as production activities increased to improve the economy. In this study, they used SO2 and smoke particles as measures of environmental degradation. They confirmed the existence of the EKC in that at low levels of growth, the levels of S02 and smoke were high, reaching a turning point after which the decline was associated with increased economic growth.

2.2.2 Ecological Modernization Theory

In the 1980s, a group of scholars at the Free University formulated the ecological modernization theory based on technology for environmental reforms (Mol and Sonnenfeld, 2000). In the late period of 1980, the role of the state and the market in the ecological transformation was emphasized by Weale (1992). Hajer (1995) stressed the role of institutional and cultural dynamics for environmental reforms. The change in ecological modernization is thus, categorized into five groups; a) the uses of science and technology to improve the environment; b) increasing the roles of the market and players in the economy such as producers to improve the environment; c) modernization of the state in terms of decentralization, flexibility to ensure that policies that promote environmental improvement and sustainability are put into action; d) social inclusion in terms of decision- making on environmental improvements; and, e) changes and abandoning environmental policies that no longer promote the improvement of the environment. Societies and economies thus, benefit from actions that move towards environmentalism. The ecological modernization theory helps countries achieve desired emissions levels through science and technology, involving those involved in production activities and social inclusion. Science and technology ensure that the most current policies that are effective in improving the environment are selected. It ensures that the rejection of policies to improve the environment is reduced through social inclusion in the decision-making process.

2.2.3 Inclusive Green Economy Theory

The inclusive green economy is concerned with attaining sustainable development in economies through poverty eradication, improved sharing of growth, and safeguarding of planetary boundaries (UNEP, 2016). The dependence on renewable energy technologies has a significant role in poverty reduction, economic activities, education, and healthcare, among other benefits. The inclusion of green economy theory emphasizes the accumulation of renewable natural capital by economies such as clean physical capital, which include; use of solar panels, wind turbines, proper management of waste, the use of efficient energy equipment in production as well as social capital which entails social opportunities and services available to all persons, access to justice among others. The production activities are to be carried out environmentally friendly and promote social inclusion through renewable energy technologies. They would ensure that the levels of environmental degradation are minimized.

2.2.4 Energy Consumption Theory

The energy consumption theory argues that energy costs can be offset by the positive economic impacts related to the utilization of energy in the production and service sectors (Vosooghzadeh, 2020). The financial outcomes, in this case, are in terms of the improvements and the innovations that take place in energy use. The positive impacts are caused by the residual and incremental innovations in businesses that improve the economy and the low cost of total energy consumption as people demand environmentally friendly energy. Initially, firms and businesses increase energy consumption which forms part of business innovation, and the consequential innovations occur in the form of lower energy cost consumption.

For instance, the initial business innovations and improvements could occur in the form of the production of sweet water by pumping the salty water from the sea, and the salted water can be desalinated. The sweet water can be used in developing both the rural and urban areas through irrigation which can attract tourism, and in this way, this would increase the consumption demand of energy. It would result in the generation of income that would improve the overall performance of the economy. This improvement would result in increased research and development to employ newer technology that reduces environmental pollution and energy production costs.

2.3 Empirical literature review

2.3.1 Influence of economic growth on carbon dioxide emissions

In 1991, Grossman and Krueger estimated the impact of NAFTA (North American Free Trade Agreement) using GEMS (Global Environmental Monitoring System) panel data. They assessed the EKC for dark matter, SO_2, and suspended particles. The findings were that SO_2 and dark matter had a turning point of $4000-5000, whereas the suspended particles were seen to reduce at low-income levels. This study is the first to confirm the existence of EKC propelled many scholars into the subject matter. The same authors, Grossman and Krueger (1993), studied the reduced form association between several environmental indicators and a country's per capita income using a dataset assembled by GEMS. The four variables used include; concentration of urban air, heavy metals in the river, measures of oxygen regime in waterways, and concentration of fecal contamination in rivers. The study concluded that economic growth leads to initial environmental deterioration but at some later point ecological improvement. The defining moment for the income per capita for the four pollutants was $8000.

In Kenya, Environmental Kuznets Curve hypothesis was investigated through a study carried out by Al-Mulali and Solarin (2015). They used data from 1980 to 2012 and applied ARDL method. Multicollinearity between GDP and its squared was controlled using Narayan and Narayan Method (2010). The study concluded that GDP, trade openness, fossil fuel, and urbanization lead to a rise in air pollution both in the LR and SR. Financial development only decreases air pollution in the LR, and renewable energy reduces air pollution in the short and LR. This study, therefore, validated that the Environmental Kuznets exists in Kenya.

Ameyaw and Yao (2018) studied how GDP affected CO_2 emissions and forecasted Africa's Total CO_2 Emissions with Non-Assumption Driven Bidirectional Long short-term memory. They surveyed five countries from West Africa (Nigeria, Ghana, Benin, Burkina Faso, and Senegal) for 2007-2014 using a panel dataset. The conclusion revealed a unidirectional causality that ran from GDP to CO_2 and from the Labor force to CO_2 emissions.

The validity of the Environmental Kuznets curve on carbon emissions for Kenya was investigated in a study by Kamande (2007) on environmental conservation as a driver of economic growth, which revealed that the EKC does not exist in Kenya. Kamande used time series data from 1960 to 2006.

2.3.2 Relationship between carbon dioxide emissions and renewable energy

Asongu et al. (2019) explored how conditionally renewable energy and environmental quality are connected in Sub-Saharan Africa and found out that there is an inverse relationship between renewable energy carbon dioxide emissions. The study sampled 40 countries from 2002 to 2017 using fixed-effects and quantile fixed effects regressions. The variables used are GDP, carbon dioxide emissions, trade, renewable energy consumption, regulatory quality, government effectiveness, and financial development. They also argued that the negative influence of renewable energy and carbon dioxide emission differs across countries based on emissions levels, meaning that countries with higher carbon dioxide emissions experience a less negative impact than countries with a lower level of carbon dioxide emissions.

Using ARDL and VECM estimation techniques, Karasoy and Akçay (2019) studied how trade and renewable energy affected environmental emissions in Turkey from 1965 to 2016. In the LR, growth in trade and nonrenewable resources raises carbon dioxide emissions, according to the findings. On the other hand, renewable energy lowers carbon dioxide emissions both in the short and long term.

Yazdi and Shakouri (2018) used the autoregressive distributed lag (ARDL) approach and vector error-correction models to study CO_2 emissions and economic growth, energy use, and renewable energy use in Germany from 1975 to 2014. They discovered that the environmental Kuznets curve was not present in Germany. Increasing the usage of renewable energy does not affect the environment and raises the cost of producing electricity, reducing the country's economic growth.

Al-Mulali et al. (2016) investigated how renewable energy production affected water, and land footprint in 58 developed and developing nations from 1980 to 2009 using the Generalized Method of Moments. The study found out that growth in GDP, urbanization, and trade openness increases the water and land footprint, while the use of renewable energy results in inefficiencies in water and land due to its positive influence on ecological footprint leading to degradation of the environment and no support for the legitimacy of the environmental Kuznets curve.

Naftaly (2017) used a Fully Modified OLS estimate to study how renewable and nonrenewable energy consumption, CO2 emissions related to economic expansion in Kenya from 1980 to 2017. The study used variable energy consumption, including renewable electricity use and oil usage, CO2 emissions, and real GDP growth. According to the study's findings, carbon dioxide emissions and electricity use harm the country's economic expansion. There is no causal relationship between economic expansion and carbon dioxide, which means economic expansion can occur without causing carbon emissions to discharge into the environment. There is unidirectional causality that runs from economic expansion to oil use and electricity use in Kenya.

2.4 Chapter Summary

Based on the various literature reviewed, a clear relationship does not exist between CO2 emissions, renewable energy utilization, and economic growth in Kenya. Thus, the study investigates the nature of the relationship between the variables that will serve as the foundation for developing various policies relating to the use of renewable energy to reduce carbon dioxide emissions while maintaining the country's economic expansion. To use renewable energy to reduce emissions would be pretty expensive for the country; thus, investigating the relationship between the three variables would help policymakers determine the appropriate policies.

CHAPTER THREE: RESEARCH METHODOLOGY

3.1. Chapter Overview

The chapter explains the approach adopted by the study to achieve the research objectives. The chapter is organized in the following way; first, the conceptual framework is discussed, followed by the theoretical and empirical frameworks.

3.2 Conceptual Framework

The framework conceptualizes the relationship between the research objectives and research questions. According to the literature, carbon dioxide emissions are affected by population, per capita GDP, and renewable energy. Population affects GDP per capita negatively and CO2 emissions positively. As the population grows, so does the demand for energy, such as coal and oil, which increases CO2 emissions. The use of solar, geothermal, biomass, wind, biofuel and tide reduce carbon emission unlike nonrenewable sources, which are harmful to the environment. As the GDP in an economy increases, there is demand for more environmentally friendly production, reducing carbon emissions. The conceptual framework is thus, summarized below.

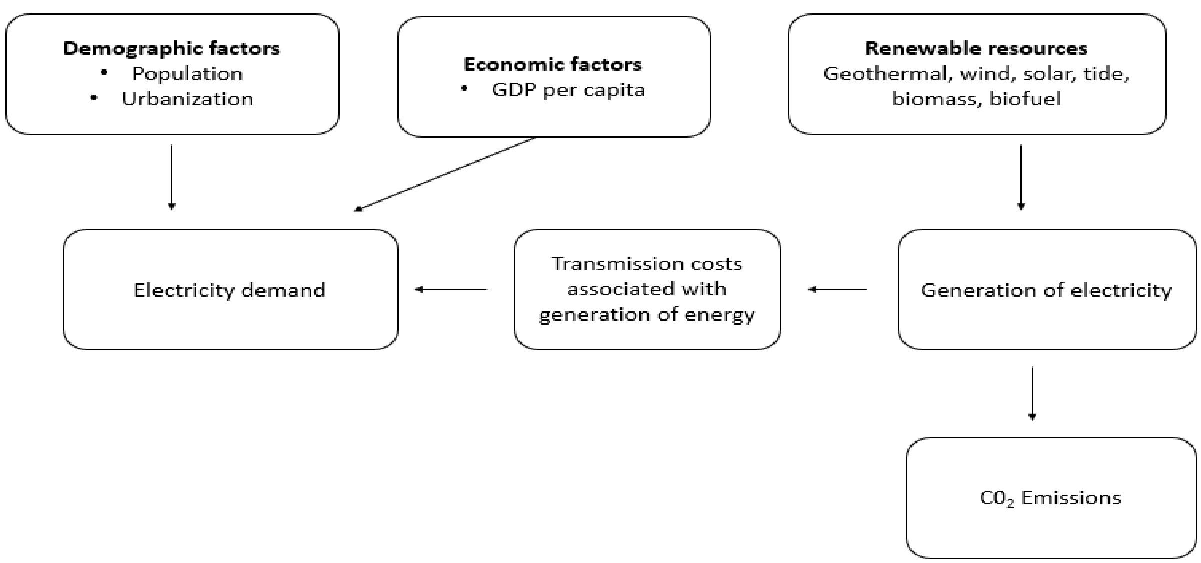

Figure 3. 1 Conceptual Framework

Source: Own Tabulations, 2021

3.3 Theoretical Framework

Ehrlich and Holdren (1971) developed the IPAT Model. The IPAT identity has been of importance to many researchers as it gives the essential drivers of degradation of the environment, which are population (P), affluent (A), and technology (T) as shown in the model below;

$$I = PAT \qquad (1)$$

Dietz and Rosa (1997) formulated the STRIPAT model (equation 2) which improved the IPAT model designed to deal with the shortcomings attributed to the IPAT model- limited applicability in hypothesis testing (York et al., 2003).

$$I = \alpha P^{\beta} A^{c} T^{d} \qquad (2)$$

Where α represents the model's coefficient while β, c, and d denote the exponentials of the independent variables population, affluent, and technology. In the study, I describe the per capita CO2 emissions; the urban population ratio represents P, Affluent is represented by GDP per capita, while technology is represented by the electricity produced from renewable energy. The STRIPAT identity is expressed as a logarithmic function as below;

$$ln\, I = ln\alpha \ + \beta\, ln\, P \ + c\, ln\, A \ + d\, ln\, T \ + ln\, e \qquad (3)$$

The STRIPAT Model in the study is given by;

$$\ln(CO_2)_t = \alpha_0 \ + \ \alpha_1 ln\, GDP_t + \alpha_2 ln\, UR_t \ + \alpha_3 ln\, RE_t \ + U_t \qquad (4)$$

The use of the ARDL model analyzes how the independent variables affect CO2 emissions.

3.4 Empirical Framework

The study employed the ARDL model which was enhanced by Pesaran et al. (2001) in testing for the presence of cointegration and the LR and SR relationship between variables. The ARDL is preferred to the other cointegration tests due to the advantages it possesses. Its applicability to time series data at stationary level, first difference, or both. The ARDL involves the Granger causality to cater to the issues associated with the approximation of short-run data. It is also preferred as it uses one equation compared to the Johansen Cointegration Model.

The bound testing takes place first in the estimation of the model using the F-statistic. There are two bounds of critical values that are important in carrying out the comparison; one involving a small sample calculated by Narayan (2005) which consists of a sample size of n = 30, and one that involves a large sample size where n lies between 500-1000 calculated by Pesaran and Pesaran (1997).

The bounds, in this case, are determined by order of integration in terms of the upper and the lower bound. It is assumed that the variables are at first difference stationary for the upper bound and at stationary level for the lower bound. The null hypothesis of non-cointegration among variables is rejected when the F-statistic is greater than the upper critical bound, meaning cointegration among variables. It is not negated if the F-statistic is smaller than the lower critical bound, meaning no cointegration. However, the test is inconclusive if the value of the test statistic lies within the upper critical and lower critical bound. Equation 5 below represents the LR and SR model;

$$
\begin{aligned}
\Delta \ln(CO_2)_t = \alpha_0 &+ \sum_{i=1}^{K} \alpha_1 \Delta \ln(CO_2)_{t-1} + \sum_{i=1}^{K} \alpha_2 \Delta \ln GDP_{t-1} \\
&+ \sum_{i=1}^{K} \alpha_3 \Delta \ln UR_{t-1} + \sum_{i=1}^{K} \alpha_4 \Delta \ln RE_{t-1} + \sum_{i=1}^{K} \lambda_1 \Delta \ln(CO_2)_{t-1} \\
&+ \sum_{i=1}^{K} \lambda_2 \Delta \ln GDP_{t-1} + \sum_{i=1}^{K} \lambda_3 \Delta \ln UR_{t-1} + \sum_{i=1}^{K} \lambda_4 \Delta \ln RE_{t-1} + U_t \quad (5)
\end{aligned}
$$

Where the coefficient α_0 is a constant. The coefficientsα_1,α_2,α_3, α_4 represents the short-run error coefficient dynamics of the model while λ_1,λ_2,λ_3, λ_4 represents the LR dynamics of the model. U_t is the error term of the model.

For the null hypothesis: λ_1=λ_2=λ_3= λ_4 = 0; there is no LR relationship with the alternative hypothesis; H_a= $\lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq 0$ indicating the presence of cointegration.

The SR coefficients are investigated using the Error-Correction Model (ECM) by determining the significance of the Error-Correction term of the model as shown in equation 6.

$$
\begin{aligned}
\Delta \ln(CO_2)_t = \alpha_0 &+ \sum_{i=1}^{K} \alpha_1 \Delta \ln(CO_2)_{t-1} + \sum_{i=1}^{K} \alpha_2 \Delta \ln GDP_{t-1} \\
&+ \sum_{i=1}^{K} \alpha_3 \Delta \ln UR_{t-1} + \sum_{i=1}^{K} \alpha_4 \Delta \ln RE_{t-1} + \theta^{*} ECT_{t-1} \quad (6)
\end{aligned}
$$

$\theta^* ECT_{t-1}$ measures the responsiveness of the variables to adjust to the long-run equilibrium level. The ECM is significant and valid if negative, thus establishing the long-run relationship (Banerjee et al., 1998).

3.5 Measurement and description of variables

The variables used are GDP per capita measured in constant 2015 US $, Urbanization given by urban population divided by total population estimated in total number annually, CO2 emissions, and clean energy as described in the table below.

Table 3. 1 Definition, notation, source, and expected sign

Variable	Type	Description	Measurement	Expected sign
CO2	Dependent	Carbon dioxide emissions	Metric tons per capita	No prediction
GDP	Independent	The Gross Domestic Product per capita	Constant LCU constant 2015 US $	Positive
UR	Independent	Urbanization	Percentage of the total population	Negative
RE	Independent	Electricity produced from renewable energy	Kilowatt per hour(kWh)	Negative

Source: Own Tabulation

3.6 Sources of Data

The study used time-series data from the World Bank website from 1971 to 2015 for the variables CO2 per capita, per capita GDP, urbanization, and electricity produced from renewable energy.

3.7 Model Diagnostic Tests

The various tests carried out in the study include; cointegration, multicollinearity, autocorrelation, heteroscedasticity and model stability.

3.7.1 Unit root test

It is done to ensure that regression does not produce spurious results. The Augmented-Dickey Fuller test is used to check for stationarity. If a unit root exists, the variable is stationary, and if it does not exist, it needs the variable to be made stationary before carrying out the regression.

3.7.2 Multicollinearity

In the study, multicollinearity is examined to ensure that the variables are not correlated. Inflation factor. If the standard error is quite large, the less significant a variable cannot be easily relied upon. If the value of VIF is 1, it means that there is no multicollinearity between the independent variable. If the VIF value is more significant than one but less than 5, then moderate multicollinearity does not call for correction of the model. Still, if it is beyond 5, then there is high multicollinearity which cannot be ignored. Correcting multicollinearity would be to drop variance with a high VIF and rerun the regression.

3.7.3 Autocorrelation

In the study, the presence of autocorrelation is tested using the Durbin-Watson test. The autocorrelation can either be positive, negative or no autocorrelation. Serial correlation is also examined in the model.

CHAPTER FOUR: RESULTS AND DISCUSSIONS

4.1 Chapter Overview

The chapter discusses the study's findings, including the descriptive statistics, correlation matrix, stationarity test cointegration test, and ARDL Model results.

4.2 Descriptive Statistics

The basic characteristics of the variables are described in the table below. The kurtosis values of a normal distribution lie between -3 and 3, while skewness lies between -0.5 and 0.5. For a normal distribution, the mean and median of the variable are expected to be equal.

Table 4. 1 Descriptive Statistics

stats	Carbon dioxide emissions	Per capita GDP	Renewable energy	Urbanization
No. of observations	45	45	45	45
Mean	-1.326	6.968	19.94	2.880
Median	-1.390	6.953	20.05	2.870
Minimum	-1.670	6.760	18.43	2.378
Maximum	-0.961	7.198	22.26	3.245
Standard deviation	0.198	0.0817	1.056	0.224
CV	-0.149	0.0117	0.0530	0.0777
Skewness	0.322	0.740	0.207	-0.300
Kurtosis	1.996	4.311	2.192	2.436

Note: All the variables are expressed in logarithm form

Source: Author's Computation

All of the variables' means and medians are nearly equal, indicating that the data is symmetrically distributed. All variables, with the exception of per capita GDP, are moderately symmetrical based on the skewness values. Per capita GDP has a skewness of 0.740, indicating that it is considerably skewed to the right. The kurtosis results of all the variables except for per capita GDP indicate that the data is normally distributed.

4.3 Correlation Analysis

According to the correlation matrix in table 4.2, carbon emissions and per capita GDP have a positive association, as predicted by the hypothesis. Although positive, the association between carbon emissions and renewable energy is statistically insignificant at the 5% level. Carbon emissions and urbanization, are inversely correlated implying that increasing urbanization helps to reduce carbon emissions, however the association is not significant.

Table 4. 2 Correlation Matrix

	Carbon dioxide emissions	Per capita GDP	Renewable energy	Urbanization
Carbon dioxide emissions	1			
Per capita GDP	0.163	1		
Renewable energy	0.127	0.8310**	1	
Urbanization	-0.240	0.7196**	0.7882**	1

Note: **Indicates 5% level of significance

Source: Author's Computation

4.4 Stationarity Test

Carbon emissions, per capita GDP, and renewable energy are all integrated to the first order and become stationary at the first difference a shown in table 4.3. Log urbanization, on the other hand, is stationary at the level and integrated to order 0.

Table 4. 3 ADF Unit root test

	Unit root test	Variable	Carbon dioxide emissions		Per capita GDP		Renewable energy		Urbanization	
		Restriction	Trend	No trend	Trend	No trend	Trend	No trend	Trend	No trend
Level	ADF	T-test	-3.53	-2.95	-3.532	-2.952	-3.5	-2.95	-3.532	-2.95
		Inference	I (1)						I (0)	I (1)
1st Δ	ADF	T-test	-3.528**	-2.90**	-3.532**	-2.952**	-3.528**	-2.950**	-	-
		Inference	I (0)						-	-

Note: ** 5% level of significance

Source: Author's computation

4.5 Cointegration Test

The LR relationship between carbon emissions, per capita GDP, renewable energy, and urbanization was tested based on bound tests. The maximum lag selection criteria were based on AIC, as shown in Table 4.4 below. The model adopted four lags based on AIC.

Table 4. 4 Maximum Lag Selection Criteria

Lag	LL	LR	df	p	FPO	AIC	HQ	SBIC
0	79.637				2.90e-07	-3.6896	-3.6287	-3.52242
1	299.24	439.2	16	0.000	1.40e-11	-13.6213	-13.3169	-12.7854
2	334.21	69.952	16	0.000	5.80e-12	-14.5469	-13.9990	-13.0423*
3	352.41	36.386	16	0.003	5.60e-12	-14.6539	-13.8625	-12.4806
4	377.02	49.233*	16	0.000	4.1e-12*	-15.0742*	-14.0393*	-12.2322

Note: * denotes the optimal lag length

Source: Author's Computation

The F-statistic value of 10.77 is greater than 3.77, 4.35, 4.89 and 5.61 implying LR relationship among the variables as shown below;

Table 4. 5 Bound test results

	Critical f- values							
	0.1		0.5		0.25		0.01	
F-statistic	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
10.77	2.72	3.77	3.23	4.35	3.69	4.89	4.29	5.61

Source: Author's Computation

4.6 ARDL Regressions

There exists a LR relationship between carbon emissions, per capita GDP, renewable energy, and urbanization is shown in below.

Table 4. 6 ARDL Results

Variable	Coefficient	Standard error	T-statistic	P-value
Adj	-0.5917**	0.1446	-4.09	0.000

Per capita GDP	1.6834**	0.3692	4.56	0.000
Renewable energy	0.0329	0.1346	0.24	0.809
Urbanization	-0.3161	0.4993	-0.63	0.532
Constant	-7.7461**	2.0374	-3.80	0.001
R^2	0.7354			
Adj R^2	0.622			
Log-likelihood	61.2891			
Root MSE	0.0657			
N	41			

Note: ** 5% level of significance

Source: Author's computation

The ECM is -0.59, which is significant and negative as expected. The speed of conversion of any changes from the LR is 59.17%. Estimated coefficients reveal a positive and significant relationship between carbon emissions and per capita GDP in the LR. A 1% increase in per capita GDP holding all other factors constant leads to a 1.68% increase in carbon emissions at a 5% significance level. Al-Mulali supports this finding, et al. (2015) concluded that GDP increases carbon emission in the LR. People are more concerned with acquiring basic needs compared to their preference for a clean environment. Fossil fuel consumption in Kenya constitutes 17.4 % of total energy consumption (World Bank, 2014). The poor people in Kenya constitute the large majority with high consumption of dirty energy as they engage in activities that increase carbon emissions.

There is a positive relationship between renewable energy and carbon emission, although it is not significant. A 1% increase in renewable energy use ceteris Paribus increases carbon emissions by 0.03%. Urbanization has a negative effect on carbon emissions, although it is not statistically significant. A 1% increase in the urban population will lead to a 0.32% decrease in carbon emissions. This finding is supported by Akorede and Afroz (2020), who found that urbanization has a negative effect on carbon emission and the urban population ratio is not significant.

The value of R^2 is 0.7354, which indicates that 73.54% of variations in carbon emissions are explained by the explanatory variables in the model while 26. 46% is unexplained by the explanatory variables in the model.

4.7 Diagnostic Tests

The serial correlation, autocorrelation and heteroscedasticity results are shown in Table 4.7, while the cumulative sum of squares of recursive residuals (CUSUMSQ) and cumulative sum of recursive residuals (CUSUM) are in figure 4.1. The variables are not serially correlated since 0.5819 is larger than 0.10. There is no heteroscedasticity meaning that there is a constant because the p-value of 0.1239 is greater than 0.10. The d-Watson value is approximately equal to 2; thus, no autocorrelation. The CUSUM results in figure 4.1 indicate model stability.

Table 4. 7 Diagnostic Tests

Tests	
Breusch-Godfrey (Serial correlation)	F= 0.309, p-value =0.5819
ARCH-LM (Heteroscedasticity)	x^2 =2.367, p-value = 0.1239
D-Watson (Autocorrelation)	d-statistic =2.114909

Source: Author's computation

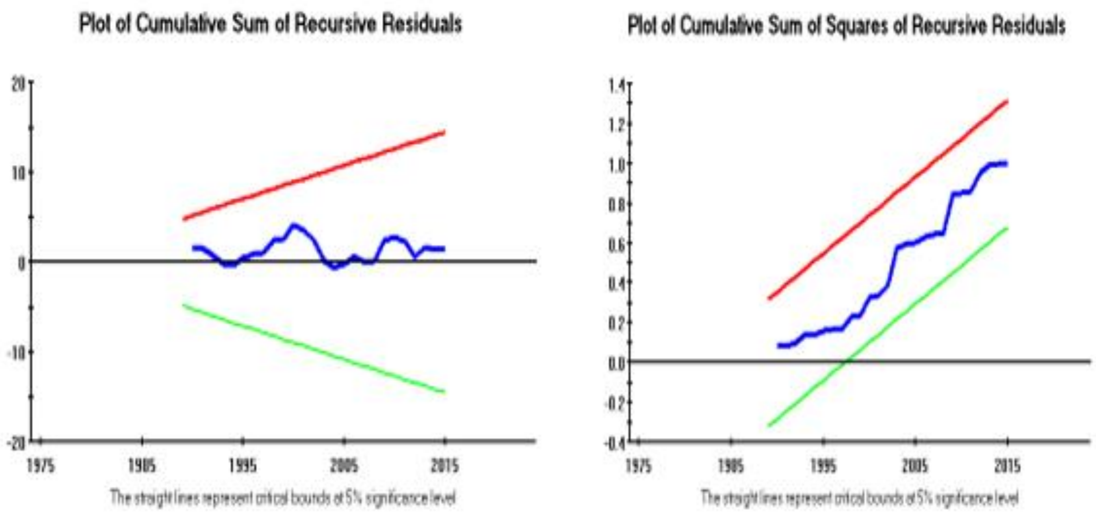

Figure 4. 1 Plot of recursive CUSUM and CUSUMQ

Source: Own Tabulation

CHAPTER FIVE: SUMMARY, CONCLUSIONS, AND POLICY RECOMMENDATIONS

5.1 Summary and Conclusion

The major goal of the research paper was to determine the relationship between carbon dioxide emissions, renewable energy use, and economic growth in Kenya. The Autoregressive Distributed Lag (ARDL) Model was used to analyze time-series data on carbon emissions, per capita GDP, renewable energy, and urbanization from 1971 to 2015. The study's data was acquired from the World Bank and analyzed using Stata 14.

The study's primary goal was to look at the influence of economic growth on carbon dioxide emissions. According to the findings, per capita GDP is a key variable in explaining carbon emissions in Kenya, and there is a proportional relationship between the two which is significant. Per capita GDP increases carbon emission as people engage in dirty activities that pollute the environment to meet their basic needs.

The second goal was to look at the influence of renewable energy on carbon dioxide emissions. The findings show that renewable energy has a positive impact on carbon emissions, however this effect is statistically insignificant at a 5% level of significance. Urbanization and carbon emissions are inversely related although the negative effect is statistically insignificant at the 5% level.

5.2 Policy Implication

The third objective was to recommend appropriate policy options that reduce pollution of the environment without compromising economic expansion. The results obtained show that carbon emissions and per capita GDP are proportionally related. Therefore, to reduce carbon emissions, policies that do not compromise economic growth should be adopted. The government can come up with policies that will move the country towards the Green Economy to ensure that it attains higher levels of economic growth at low levels of carbon. The government can promote the adoption of green technology through subsides, research and development, social inclusion to address the challenges that the Green Economy Strategy and Implementation Plan faces. The GESIP is faced with the challenge of limitation in financing as the initial phases of green technologies involve huge costs which the energy sector lacks. The government can subsidize the energy sector to encourage the use of clean energy. Funding by both international and domestic donors towards green technology should be encouraged with such funding well accounted for.

The government can increase sensitization of people towards the green economy as the people lack adequate information on green technologies which would help in promoting a low carbon economy. The citizens would also be informed more on goods and services produced from green technologies as this would ensure that technology transfer is high promotion its adoption and adaptation. The government, therefore, can fund research and development on green technology as this would provide more information on the cost- benefit analysis of adopting the green technology in production process

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APPENDIX

Appendix 1

Year	Carbon dioxide emissions	Per capita GDP	Renewable energy	Urbanization	Log CO2	Log per capita GDP	Log Renewable Energy	Log Urbanization
1971	0.31464	862.76771	101000000	10.77800	-1.15634	6.76015	18.43063	2.37751
1972	0.31882	974.13618	104000000	11.28200	-1.14314	6.88155	18.45990	2.42321
1973	0.31109	994.35006	108000000	11.80500	-1.16766	6.90209	18.49764	2.46852
1974	0.37855	997.06898	112000000	12.34900	-0.97140	6.90482	18.53401	2.51358
1975	0.36654	968.92608	116000000	12.91400	-1.00365	6.87619	18.56910	2.55831
1976	0.32700	953.25831	121000000	13.50300	-1.11781	6.85989	18.61130	2.60291
1977	0.34544	1004.70188	125000000	14.11200	-1.06295	6.91245	18.64382	2.64703
1978	0.35017	1034.13307	130000000	14.74500	-1.04933	6.94132	18.68305	2.69090
1979	0.31893	1071.15333	135000000	15.40100	-1.14277	6.97649	18.72079	2.73443
1980	0.37748	1088.37662	140000000	15.58300	-0.97423	6.99244	18.75715	2.74618
1981	0.38252	1086.64451	146000000	15.68100	-0.96098	6.99085	18.79912	2.75245
1982	0.26464	1061.19482	152000000	15.78000	-1.32938	6.96715	18.83939	2.75874
1983	0.25287	1034.52317	157000000	15.87900	-1.37490	6.94170	18.87176	2.76500
1984	0.22562	1013.38977	163000000	15.97900	-1.48892	6.92106	18.90926	2.77128
1985	0.18965	1018.11730	169000000	16.07900	-1.66258	6.92571	18.94541	2.77751
1986	0.20182	1051.74784	544000000	16.18000	-1.60038	6.95821	20.11446	2.78378
1987	0.24198	1074.61213	541000000	16.28100	-1.41888	6.97972	20.10893	2.79000
1988	0.21618	1101.52378	511000000	16.38300	-1.53166	7.00445	20.05188	2.79624
1989	0.22640	1113.89971	518000000	16.48500	-1.48546	7.01562	20.06549	2.80245
1990	0.25880	1121.97367	527000000	16.74800	-1.35169	7.02284	20.08271	2.81828
1991	0.24020	1101.11436	504000000	17.04300	-1.42630	7.00408	20.03809	2.83574
1992	0.23494	1057.61880	486000000	17.34200	-1.44844	6.96378	20.00172	2.85313
1993	0.22421	1028.45578	492000000	17.64500	-1.49517	6.93581	20.01399	2.87045
1994	0.21781	1023.64061	383000000	17.95200	-1.52415	6.93112	19.76355	2.88770
1995	0.22940	1037.26942	512000000	18.26300	-1.47230	6.94435	20.05384	2.90488
1996	0.24380	1049.25494	515000000	18.57900	-1.41142	6.95584	20.05968	2.92203
1997	0.22573	1024.62727	488000000	18.89800	-1.48842	6.93208	20.00583	2.93906
1998	0.23669	1029.13251	512000000	19.22200	-1.44100	6.93647	20.05384	2.95606
1999	0.24085	1024.13941	505000000	19.55000	-1.42360	6.93161	20.04007	2.97298
2000	0.25747	1002.37486	557000000	19.89200	-1.35684	6.91013	20.13808	2.99032
2001	0.23167	1012.26839	603000000	20.23900	-1.46245	6.91995	20.21743	3.00761
2002	0.21984	990.56824	508000000	20.59100	-1.51485	6.89828	20.04599	3.02485
2003	0.18830	992.35997	909000000	20.94800	-1.66972	6.90009	20.62786	3.04204
2004	0.20850	1015.01749	1157000000	21.31000	-1.56781	6.92266	20.86910	3.05918
2005	0.22744	1045.92472	1134000000	21.67500	-1.48086	6.95266	20.84902	3.07616

2006	0.24702	1083.32901	1138000000	22.04500	-1.39829	6.98779	20.85254	3.09309
2007	0.24208	1125.93731	1151000000	22.42000	-1.41848	7.02637	20.86390	3.10995
2008	0.24905	1097.75087	1305000000	22.80000	-1.39012	7.00102	20.98947	3.12676
2009	0.28630	1103.28187	1576000000	23.18300	-1.25073	7.00604	21.17816	3.14342
2010	0.30073	1163.89697	1680000000	23.57100	-1.20153	7.05953	21.24206	3.16002
2011	0.30177	1202.16745	1735000000	23.96900	-1.19808	7.09188	21.27427	3.17676
2012	0.27355	1223.99443	1808000000	24.37600	-1.29628	7.10987	21.31549	3.19360
2013	0.30975	1262.45384	2205000000	24.79400	-1.17198	7.14081	21.51399	3.21060
2014	0.32184	1296.47478	4234000000	25.22100	-1.13370	7.16740	22.16641	3.22768
2015	0.35695	1336.88327	4659000000	25.65800	-1.03017	7.19810	22.26207	3.24486