Aggregate and Disaggregate Analysis of Renewable Energy on Consumption-based carbon emissions: A Global Perspective with Net-importers and Net-exporters of carbon emissions

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February,2023

IN THE NAME OF
ALLAH
THE MOST MERCIFUL
THE MOST COMPASSIONATE

Certificate

This is to certify that the thesis submitted by **Faryal Hafeez** is accepted in its present form by the School of Economics, Quaid-i-Azam University, Islamabad, as satisfying all the necessary requirements for partial fulfillment of the degree of Master of Philosophy in Economics.

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DEDICATION

This thesis is dedicated to my respected teachers and beloved parents for their endless love and encouragement.

DECLARATION

I Faryal Hafeez hereby state that this thesis titled “Aggregate and Disaggregate Analysis of Renewable energy on Consumption-based carbon emissions: A global perspective with Net-importers and Net-exporters of Carbon emissions” is my own original work. I have not presented any part of this work elsewhere for any other degree previously.

Faryal Hafeez

Table of Contents

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS

Abbreviations	**Words**
GHGs	Greenhouse gases
CO_2	Carbon dioxide
CCO_2	Consumption-based Carbon Emissions
PCO_2	Production-based Carbon Emissions
SDGs	Sustainable Development Goals
GDP	Gross Domestic Product (Per Capita)
REC	Renewable Energy Consumption
ELES	Electricity Generation from Solar Energy
ELEW	Electricity Generation from Wind Energy
ELEB	Electricity Generation from Biomass and Waste Energy
ELEH	Hydroelectricity
ELEG	Electricity Generation from Geothermal Energy
FD	Financial Development
EINTS	Energy Intensity
GFCF	Gross Fixed Capital Formation
URB	Urbanization
WDI	World Development Indicator
GCA	Global Carbon Atlas
EIA	Energy Information Administration
OLS	Ordinary Least Square
EKC	Environmental Kuznets Curve

ABSTRACT

Renewable energy is clean and safest modern energy source, which serves as a pillar to meet future energy demand with environmental sustainability. Earlier researchers have investigated the role of renewable energy on emissions massively. The Effectiveness of individual renewable energy source on environment is often omitted. Therefore, this study examines the individual and relative strength of renewable energy sources by disaggregation of renewable energy according to sources of electricity production (hydroelectricity, solar, wind, biomass and geothermal). Unlike previous studies that mainly focused on terrestrial carbon emissions, present study focused on consumption-based carbon emissions. It is trade adjusted, distribute emissions responsibilities not only producers but consumer shoulders and fighting against carbon leakage. The study has extended the EKC hypothesis by incorporating renewable energy. Based on this hypothesis, current study scrutinizing impact of aggregate and disaggregated renewable energy on global panel data of 107 countries including sub-samples of net-importers of carbon emissions and net-exporters of carbon emissions over the period 1991-2021. The study has employed traditional empirical techniques pooled OLS, fixed effects and random effects along Driscoll and Kray regression method to address heterogeneity, autocorrelation and cross-sectional dependency. Moreover, the advance technique of two step system GMM is applied to address endogeneity in the models. The outcomes of traditional and advance technique of GMM indicated existence of EKC for global panel. Moreover, analysis also confirmed that EKC hypothesis is valid for net-importers of carbon emissions and net-exporters of carbon emissions. Outcomes regarding renewable energy showed its protentional role to reduce the consumption-based carbon emissions. For disaggregate analysis, outcomes indicated that electricity generation from solar, wind, biomass and geothermal energy improves environmental quality while hydroelectricity degrade the environment. Thus, current study provides the evidence of significant impact of aggregated and disaggregated renewable energy on consumption-based carbon emissions.

Chapter 01

Introduction

1.1. Background

The modern era of the world is now facing a main challenge of climate change and global warming that is caused by increasing level of Greenhouse gases (GHGs) emissions. Among all other gases carbon dioxide (CO_2) is major contributor to global warming that accounts for around 75% of Worldwide emissions (Our World data,2022). These emissions have hazardous impacts on human lives, that pointed in literature as transition risks and physical risks, including heat waves, melting glaciers, rising sea levels, flood, droughts, storms and heavy rain. (Hale, 2020; He et al., 2021; Akinsola et al.,2022). Because of these havoc impacts, international community highly concerned about environmental sustainability. Therefore, researchers are investigating the causes of carbon emissions in all over the world.

The root causes of increasing level of carbon emission are not only natural but since the 18th century, the main drivers are economic activities for example extensively burning of unsustainable energy sources (fossil fuels like oil, natural gas and coal) for consumption and production purposes, which boost up economic growth and other development processes. As statistics recorded by Our World data, 2022 that energy sector is the highest contributor to global emissions (electricity, heat and transport) about 73.2%. Over 40% of energy related CO_2 emissions are due to the burning of fossils fuels for electricity production.

Concerning predicaments of non-renewable energy sources, global developments emphasized the need for sustainable energy. As 7th sustainable development goal (SDG) listed by United nation emphasized on the "availability of clean and renewable energy for use" to achieve goal of climate change mitigation (SDG) 13. Therefore, national and international bodies took initiatives and numerous countries signed international agreements including Kyoto Protocol (1997), Paris Climate Agreements (PCA) (2015), and COP 27 in Egypt in 2022. These agreements set target to keep the temperature preferably 1.5 degree Celsius to pre-industrial level by increasing proportion of clean, efficient and renewable energy in total energy mix.

Review of literature regarding sustainable energy provide evidence that renewable energy is crucial for reduction in emissions (Shahbaz et al.,2022). Renewable energy is as excellent substitute of traditional energy sources because it provides energy security and have potential to combat environmental degradation. In this regard, most preferred energy sources are solar, biomass, wind, geothermal and hydro powers. In this perspective, researchers and policy makers are interested in exploring environmental cost effectiveness of modern energy sources and new technologies to get these energies. Moreover, increasing demand of goods and services at domestic and commercial level indirectly increased the demand of energy, whereas fossils fuel energy sources are depleting and putting pressure on prices. However, uninterrupted supply of energy is essential for economic development for all over the world (Majeed and Luni, 2019).

Additionally, Renewable energy sources do not emit substantial number of pollutants. These energy sources recharged naturally and supply of renewable energy resources do not deplete as solar, wind and biomass. Moreover, as compared to fossils fuels energy that emits 950 grams of CO_2 for every kilowatt hour of electricity, renewable energy sources emit negligible carbon emissions, as electricity production from wind energy (Wind turbines) between 4 and 25 grams and solar energy technology like photovoltaic (PV) emits carbon between 50 and 160 grams for every kilowatt hour of electricity (Poenaru et al., 2019). By accepting the importance of clean and renewable energy sources, nations are trying to increase the utilization of renewable energy in overall energy system. Therefore, in recent years, renewable energy mostly serves in electricity generation. In the end of 2021, renewable comprised about 28% of the world's electricity generation, with hydropower contributing about 15%, that expected to increase 54% in 2035 (Apergis and Payne, 2012). It is predicted that the contribution of the renewables towards overall energy sector will surge to 85% by 2050, achieved through the contribution of solar and wind energy (IRENA, 2018).

Although nations pursuit for renewable energy in total energy mix but the initiatives taken for energy transition towards renewable energy is not satisfactory because policies adopted at national and international levels are not in line that could reduce emissions at global level. It can be observed through statistics that the atmospheric level of CO_2 is rising continuously. As reported by Statista-2022 that the atmospheric level of CO_2 has raised since the 1960's from 316.91 parts per million to 416.45 parts per million in 2021. Global CO_2 rebounded to their highest level in history in 2021 (IEA, 2022). Globally carbon emissions from fossils fuels, industry and land changes in 1950 were 11.43 billion tons that have reached almost 41.06 billion tons in 2021 (Our World Data, 2022). Moreover, the rise in CO_2 changed from one region to another region and country to country (Renewable system, 2013). According to Our World Data (2022) almost in the mid of 20th century emission rise across Asia, mostly in China and India while US and Europe have one third of emissions that was in 1900, more than 90% and in 1950, 85% of emissions

Thus, initiatives taken by regions and countries just changed the outlook of the structure of emissions at global level rather reduce emissions. Policies adopted by countries especially, advanced countries transfer emissions to other emerging markets resulting global emission rising continuously. One reason that hindered for the achievement of global carbon reduction is accounting method to measure emissions.

1.1. Production versus Consumption-based accounting of carbon emissions

Traditional methods known as terrestrial or production-based accounting captured emissions within a nation border that is emitting directly and do not adjusted emissions embodied in trade. International climate treaty paid little attention to current trade pattern and trade is not captured within global climate policy, finally resultant that global carbon emissions continue to rise (Barrett et al. 2013).

Policies recommended on the bases of traditional accounting methods that accounts only those emissions produced within a terrestrial boundary, measuring criteria set by United Nation neglect the responsibilities of consumers who take benefits from international trade. Moreover, policies based on production-based paradigm put responsibilities on producer's shoulders (Grasso 2016; Rocco et al. 2020; Kirikkaleli et al. 2021). There are low carbon emissions in those regions of world, where countries import consumer goods more than it produces (Iqbal et al.,2021).

Peter and Hertwich (2008) pointed international trade as a "rational option for consumers" that provide mechanism to transfer environmental pollution embedded with their consumable items to distant land, and shifts emissions from one region to another region. Production-based carbon emissions paradigm sourced Carbon leakage through shifting carbon intensive industries to other nations (Adebayo et al. 2021). As developed countries decarbonize by increasing demand of goods from emerging markets especially from developing countries, those planted energy-intensive industries in recent years. (Kirikkaleli et al., 2021, Yan et al., 2020 and Kirikkaleli et al. 2022).

Thus, traditional accounting method sourced carbon leakage that creating inequity of emissions at regional and country level while could not achieve fruitful results in global emission reduction. It has been observed from global outlook of carbon emissions. Therefore, the main focus should be on distribution of trade-related emissions (Najibullah et al., 2021).

Limitations of traditional production-based carbon emissions divert our attention towards carbon accounting adjusted for trade that can be used for better policy recommendation for achievement of 2030 global goals for sustainable development along sustainable environmental quality.

On the other side, consumption-based accounting highlight countries consumption pattern through capturing emissions for consumption items within country and also known as carbon footprint. Consumption-based accounting is differed from traditional methods of accounting because it also covers the indirect causes of CO2 emissions i.e., international trade (Davis and Calderia, 2010).

In consumption-based accounting method, all emissions connected with exported goods are deducted from domestic emissions and included transportation and imported goods emissions. This accounting, measures carbon, embedded in imported goods and exported goods and services via international and inter-regional trade, therefore it is called trade adjusted accounting. Consumption-based emissions is a part of traditional-based emissions but adjustment for trade depicts the consumption pattern of a country.

Consumption-base accounting is a good measure in mitigation of climate change. because it distributes the emissions responsibilities not only producers but also on consumer's shoulders. This accounting measures gives clear and consistent description of a nation’s environmental pressure regarding “who is actual responsible of global emissions, producers or consumers?” Moreover, policies regulating by consumption-based accounting approach is more effective way for reduction of global carbon emissions because this accounting method fight against carbon leakage and negate shifting of carbon intensive industries from one region to another region.

Studied by Rocco et al. (2020) revealed that consumption-based accounting policy reduce CO2 emissions globally almost 1.2 Gton while policies impose through production-based accounting would increase global emissions almost 0.8 Gton. Policies implement by considering consumption-based carbon emissions will give more weightage for the utilization of sustainable energy within a country, because consumer will demand goods and services produced locally and internationally that embodied less amount of carbon emissions. Therefore, serious efforts will be taken by governments for energy transition towards renewable energy for emission mitigating purposes.

1.3. Renewable energy and Consumption-based carbon emissions

Efficient use of renewable energy has positive role in reduction of consumption-based carbon emissions (Adebayo et al., 2021; Danish et al., 2022 and Kirikkaleli et al., 2022). As consumption-based emissions depends upon emissions embodied in domestic produced goods that are consumed with in nation and imported goods. Utilization of renewable energy in production processes and supply chains that involves in manufacturing, electricity and transportation will reduce emission intensity of production and less amount of carbon will be embodied in those goods (Peter and Hertwich, 2008).

Increase in application of renewable energy as a fuel for public and private vehicles, decrease the emission of transportation and will results in controlling of consumption-based carbon emissions (Amin et al., 2020). For example, increase in consumption of electronic cars that use renewable energy will help in reduction of consumption-based carbon emissions. Moreover, installation of renewable energy e.g., Solar Photovoltaic cells on the roofs of houses and offices will provide sustainable electrical energy for durable items such as refrigerator, LED, air conditioners, washing machines and other electronic appliances which reduce consumption-based carbon emissions (Kirikkaleli et al., 2022).

Though Empirical literature investigated that renewable energy is favorable for improving environmental quality but some studies empirical results are not consistent with theory they indicated that combustible energies are not save and clean sources of renewable energy. Moreover, sperate studies on hydroelectricity or biomass waste provide contentious results and provide evidence that different sources of renewable energy have different effect and role on emissions. Given that renewable energy is considered as an elixir for a sustainable energy future. It would be important to investigate the role of renewable energy sources separately on carbon emissions in order to explore the beneficial source of energy for sustainable growth without compromising environmental quality.

1.4. Research Gap

Review of literature nexus between renewable energy and environmental sustainability along EKC hypothesis reveals various shortcoming in the empirical studies. Firstly, previous empirical studies mainly focus on traditional production-based carbon emissions to measure environmental degradation. However, production-based carbon accounting could not help out in global emission reduction processes. Moreover, literature is missing at global level regarding trade adjusted emissions. The proxy of consumption-based carbon emission is not empirically measured for global analysis.

Secondly, literature review on nexus between renewable energy and carbon emissions is indicating that previous studies did not investigate for disaggregated analysis of renewable energy. However, previous studies have incorporated aggregated renewable energy and empirical analysis available for a single source of renewable energy in the EKC models. However, those studies did not explain the comparative strength or individual explanatory power of different renewable energy sources separately on carbon emissions at global level.

Thirdly, empirical analysis is not available regarding relationship between disaggregated renewable energy and consumption-based carbon emissions. Forth, previous studies did not sample the global data into net-importers and net-exporters of carbon emission countries. Literature is silent regarding empirical analysis of nexus between aggregated and disaggregated renewable energy and consumption-based carbon emissions for net-importers and net-exporters of carbon emissions. Therefore, empirical analysis is required for disaggregated renewable energy.

1.5. Research Objective

The present study focuses to achieve following main objectives.

- To investigate the existence of EKC globally and for net-importers and net-exporters of carbon emissions for 1990-2021, in the context of consumption-based carbon emission.

- To assess potential of renewable energy at aggregate level on consumption-based carbon emissions.

- To investigate more effective source of renewable energy by disaggregating into electricity generation from solar, wind, biomass, geothermal and hydroelectricity to reduce consumption-based carbon emissions.

1.6. Research Question

Our empirical study will focus on the following key questions for achievement of the objectives:

- Does non-linear relationship exist in between economic growth and CO_2 emissions, does EKC exist globally and for net-importers and net-exporters of emission countries from 1990-2021.

- Does all resources of renewable energy are environmentally friendly if they utilized for electricity generation from renewable sources. Are renewable energy sources a better determinant Consumption-based carbon emission.

- Are the impacts of disaggregated renewable energy (solar, wind, biomass, geothermal and hydroelectricity) use similar in net-importers and net-exporters of emission countries.

1.7. Hypothesis to be tested

The current study will test the following hypothesis empirically.

Hypothesis 1:

H_0: The relationship is non-linear between income per capita and consumption-based carbon emission.

H_1: The relationship is linear between income per capita and consumption-based carbon emission.

Hypothesis 2:

H_0: Aggregate renewable energy reduces consumption-based carbon emissions in linear relationship.

H_1: Aggregate renewable energy does not reduce consumption-based carbon emissions in linear relationship.

Hypothesis 3:

H_0: Electricity generation from solar energy reduces consumption-based carbon emissions in linear relationship.

H_1: Electricity generation from solar energy does not reduce consumption-based carbon emissions in linear relationship.

Hypothesis 4:

H_0: Electricity generation from wind energy reduces consumption-based carbon emissions in linear relationship.

H_1: Electricity generation from wind energy does not reduces consumption-based carbon emissions in linear relationship.

Hypothesis 5:

H_0: Electricity generation from biomass energy reduces consumption-based carbon emissions in linear relationship.

H_1: Electricity generation from biomass energy does not reduce consumption-based carbon emissions in linear relationship.

Hypothesis 6:

H_0: Electricity generation from hydroelectricity reduces consumption-based carbon emissions in linear relationship.

H_1: Electricity generation from hydroelectricity does not reduce consumption-based carbon emissions in linear relationship.

Hypothesis 7:

H_0: Electricity generation from geothermal energy reduces consumption-based carbon emission in linear relationship.

H_1: Electricity generation from geothermal energy does not reduces consumption-based carbon emission in linear relationship.

1.8. Contribution in Literature

This study contributes in existing literature from many aspects. First, substituting non-renewable energy sources to renewable energy sources improves the sustainable consumption. Second, Previous studies have widely incorporated the aggregate renewable energy or a single source of renewable energy in the EKC hypothesis which could not explain the comparative strength or individual power of different renewable energy sources separately on carbon emissions at global level. Present study therefore contributes to fill this important gap by disaggregating renewable energy into five different sources solar, wind, biomass and waste, hydroelectricity and geothermal energy and empirically analyses the impact of disaggregate renewable energy on consumption-based carbon emissions from global perspective.

Second, present research contributes in the literature by studying the new method to measure quality of environment that is consumption-based accounting. This study therefore contributes to fill this knowledge gap by investigating the impact of different sources of renewable energy on consumption-based carbon emissions. This accounting method will guide policymakers, and has potential for better policy formulations. Third, by categorization of data into net importers and exporters of emissions have intensity to provide guideline to policymakers regarding carbon leakage through international trade and distribution of emissions responsibilities. Lastly, this study uses newly available data timespan from 1990-2021 and exploits the modern econometric technique of fixed effect Driscoll-Kray robust standard error estimation to control heterogeneity, autocorrelation and cross-sectional dependency and twostep system GMM to address the endogeneity problem.

1.9. Structure of Thesis

The remaining work of this study is organized as follows: chapter two is providing the theoretical and empirical evidence in the support of the study, relating to the relationship in between renewable energy sources and environmental sustainability indicators. Next chapter 3 is providing the detail information about the theoretical and empirical model, which is used in this study. Chapter 4 is explaining the data and variable description in detail. Chapter 5 is depicting the complete data analysis both graphical and statistical. Next chapter 6 is providing the regressions outcomes obtained by estimation techniques. Lastly, chapter 7 is providing the conclusion of the whole study with detail results information and also discusses the study limitation and policy recommendations.

Chapter 02

Literature Review

2.1. Introduction

The present chapter highlight the existing literature about the relationship between renewable energy, economic growth and carbon emissions. The first section of this chapter will reveal the overview of existing economic theory related to environment. Second section will provide the overview of existing empirical literature regarding relationship between renewable energy and carbon emissions in the context of EKC-hypothesis. Both theoretical and empirical evidence provided in next sections.

2.2. Theoretical Literature

In the modern era, international community highly concerned about environmental sustainability. Therefore, to combat the hazardous of climate change is main agenda of global researchers. Under this senecio, present section is highlighting the theoretical evidence regarding quality of environment, economic growth and energy consumption. The theoretical foundation of the present study is based on EKC theory and social choice theory.

Environmental Kuznets Curve Hypothesis:

The concept of EKC model emerged in the early 1990’s, first proposed by Grossman and Krueger, (1991) and comes from the original Kuznets “Inverted-U shaped hypothesis” developed by S. Kuznets (1955), according to this hypothesis income inequalities increases in the early stage of economic development and decrease later after getting a specific level of income. On the bases of this line EKC hypothesis indicates nonlinear relationship in between economic development and environmental indicators. On the basis of EKC hypothesis, GDP degrades the quality of environment at initial stages but as the economies are moving towards higher level of income continuously, quality of environment starts improving.

The EKC hypothesis is grouped into three stages: scale effect, structural or composite effect and technique effect, explained in studies (Grossman and Kruger, 1995) and (Stern, 2004). The first stage is scale effect, where countries major concern is economic development and are compromising environmental quality. As economy expand in early stage more pollution intensive technologies and non-renewable energy sources utilized in production methods and culminating environmental quality, Awosusi et al., (2021). This stage is more experienced by developing countries, as over the path of development, countries move from agriculture sector to industrial sector. The second stage of the EKC theory, implies that as economies continue growth process and moves from pre industrial sector to manufacturing and manufacturing to service sector gets a certain level of income, they become concern with environmental hazards and more conscious about sustainable development. In this stage environmental quality and economic development both are beneficial, here composite or structural effect dominate, at this level environmental degradation is experienced but reached at turning point, Adebayo et al., (2021). The third stage is the technique effect, where technological advancement, availability of clean technology such as renewable energy enhance economic development without compromising environmental quality (Majeed and Mazhar., 2020). This stage experienced by developed countries where their economic activities move on service sector and clean and advance technology is driven.

Social Choice Theory

Social choice theory emphasizes on the preferences of societies about collective welfare. This theory also related to the third stage of EKC hypothesis, which stresses on the environmental sustainability at global level. According to social choice theory, demand for clean environment is first priority for better living standard, therefore, societies move their economic activities towards collective welfare, from individual preferences to social preferences. Producers and consumers may more concern about quality of environment, therefore, demand for renewable and clean energy sources increase and societies make efforts to search for clean resources.

Ecological Modernization Theory

According to ecological modernization theory (1980), efficient use of natural resources serves as a determinant of environmental productivity. This theory suggested that increase in the use of efficient modern energy sources and substituting environmental hazardous technologies into clean modern technologies will improve quality of environment. Moreover, this theory also developed the concept of "sustainable household", which emphasized the individual choices about consumption pattern that effect quality of environment.

2.3. Empirical literature Reviews

The empirical validation of EKC hypothesis has been investigated in research but outcomes of the studies are mixed. The EKC hypothesis is not studied single, mostly researchers have incorporated other economic indicators such as energy production and consumption, urbanization, trade, education, biocapacity, Foreign direct investment financial development and inflation.

Numerous studies explored the relationship between renewable energy, economic growth and environmental quality in the context of EKC hypothesis but studies mainly focused on aggregate renewable energy. The number of studies is quite few that focused on relationship between disaggregate renewable energy, economic growth and carbon emissions. In this regard, we categorize the literature into two sections. In first section, we highlighted the literature about aggregate renewable energy, economic growth and carbon emissions while second section provides the evidence about the relationship between disaggregate renewable energy, economic growth and carbon emissions.

In this section, the recent studies on renewable energy use and environmental quality have been discussed that have been calculated in different countries of the world. The commonly used methods in these studies are time series and panel data models.

2.3.1. Aggregated Renewable Energy and Carbon Emissions

Over the last few years several studies (Wiebe, 2016; Balsalobre-Lorente et al, 2017; Sinha and Shahbaz, 2018; Majeed and Luni, 2019; Saidi and Omri, 2020; Khan et al., 2020; kirikkaleli et al., 2021; Ding et al., 2021; Kirikkaleli and Adebayo, 2021; Ibrahim and Ajide, 2021; Adebayo et al., 2022; Danish et al., 2022) have explored the renewable energy-environment nexus.

In the case of developed economies, Balsalobre-Lorente et al. (2017) studied the role of electricity from renewable sources on environmental sustainability in five European Union countries (EU-5), by utilizing annual data set from 1985-2016. According to outcomes there exists significant relationship between renewable energy and carbon emission in the EU-5 countries with N-shaped EKC curve in contrast to above finding Boluk and Mert (2014) examined EU countries for the period from

1990-2008 and indicated that renewable energy deteriorates the environmental quality.

For the case of developed world, different studies have different outcomes as one of the studies conducted by Danish et al., (2022) on OECD countries from 2005-2016, documented negative and significant effect of renewable energy on accounting of consumption-based carbon emissions by utilizing Dricoll-Kraay fixed effect regression method and confirms validity of EKC for OECD countries.

Similarly, study on OECD countries over the period 1990-2018 conducted by Saidi and Omri, (2020) the outcomes by FMOLS revealed that renewable energy improves environmental quality in Germany, Belgium, Sweden, France, US, Japan, UK, Czech Republic, Finland and Switzerland. However, it deteriorates the environmental quality in Netherland and south Korea.

Additionally, Ibrahim and Ajide, (2021) analyzed G-7 countries from 1990-2019 by employing Wester Lund cointegration test and pooled mean group (PMG) techniques. Results proved that renewable energy is beneficial for G-7 countries. Moreover, results confirmed long-run relationship for countries with the context of EKC.

Ding et al. (2021) also examined the G-7 countries over annual data from 1990-2018 and confirmed that renewable energy is an important tool for the reduction of consumption-based carbon emissions Their analysis showed that renewable energy consumption, eco-innovation and energy productivity improves environment.

The study of Sinha and Shahbaz, (2018) found Indian economy can move on sustainable path by utilizing renewable energy. outcomes for the period of 1971-2015, results showed significant and negative relationship of electricity generation from renewable energy on carbon emission.

Similarly, Kirikkaleli and Adebayo, (2021) investigated the nexus between consumption-based carbon accounting and renewable energy for India on quarterly data 1990Q1-2015Q4 by employing Dynamic Ordinary Least Square (DOLS) econometric technique and Fully Modified Ordinary Least Square (FMOLS) technique. Their analysis showed, renewable energy and public-private partnership investment in energy sector has potential for improving quality of environment.

Another study by Kirikkaleli et al., (2021) investigated the long-run and causal impact of renewable energy with consumption-based carbon in Chile. By collecting annually dataset spanning between 1990 and 2017, Outcome revealed that renewable energy improves the environmental quality by reducing consumption-based carbon emissions in Chile. However, Al-Mulali et al. (2015) studied Vietnam for the period from 1981 to 2011 and reported insignificant outcomes of renewable energy on carbon emissions.

Majeed and Luni (2019) analyzed using a data of 166 countries for the period of 1990-2017 and investigated the impact of renewable energy and water withdrawal on carbon emissions by employing panel estimation techniques (fixed effect, random effect and two stage least square). Their finding supports renewable energy are beneficial tool to mitigate environmental hazards while water withdrawal degrades environment.

In contrast to above results, findings by Dong et al. (2020) analyzed the sample of 120 countries along income based sub-samples over the period 1995-2015. By considering cross-sectional dependency and slope heterogeneity in model, the outcome showed, renewable energy reduces carbon emissions but results are insignificant. The analysis exposed that higher economic growth and use of non-renewable resources at large scale faded the positive effects of renewable energy. Moreover, validation of EKC hypothesis is confirmed for global panel of 120 countries, while further analysis on upper middle- and high-income countries also validate the EKC hypothesis.

Al-Mulali et al. (2017) by employing fixed effect and advance technique of system and difference Generalized method of moment (GMM) investigated 58 countries over the time span 1980-2009. Countries sampled into developing and developed countries for estimation and the outcomes indicated unpleasant role of renewable energy to improve the environment quality.

Khan et al. (2020) studied G-7 countries for time period 1990-2017 by using consumption-based accounting method to measure the quality of environment. Outcomes depicted the long-run relationship is existing in between economic growth and consumption-based carbon. Moreover, results also validated the effective role of renewable energy to reduce consumption-based carbon. Results are also confirmed by employing Augmented mean group estimation and Common correlated effect mean group techniques. Further, causality test also confirmed the causal relation between Renewable energy and consumption-based carbon.

2.3.2. Disaggregated Renewable energy and Carbon Emissions

Over the last few years few studies (Destek and Aslan, (2019); Balezentis et al. (2019) Sahoo and Sahoo. (2022); Bilgili et al. (2016); Dogan and Inglesi -Lotz. (2017); Bilgili et al. (2021); Solarin et al. (2018) and Majeed et al., (2022) has explored the role of disaggregate renewable energy on emissions. Available evidence gives mixed results and evidence on disaggregate renewable energy and carbon emissions are not giving conclusive outcomes.

Destek and Aslan, (2020) explored the relationship between wind, solar, biomass and hydroelectricity and carbon emissions in G-7 countries from 1991-2014. By using Augmented Mean Group (AMG), it is empirically estimated that hydroelectricity, biomass and wind energy consumption reduce carbon emissions while solar energy reduce emissions but results are insignificant about solar energy for G-7 countries. Similarly, Balezentis et al., (2019) investigated 27 EU-economies over the period 1995-2015 and showed solar, wind, geothermal and biomass significantly improve environmental quality.

The studies examining the hydroelectricity on emissions have increased in recent years. Sahoo and Sahoo, (2022) examined the hydroelectricity-Environment nexus in India from 1965-2018 using Toda-Yamamoto approach study found out one way causality from hydroelectricity to carbon emissions. Moreover, ARDL bound testing approach revealed long-run results that hydroelectricity increased carbon emissions in India.

Another study by Bilgili et al., 2021 by using wavelet transform model for the period 1980-2019 revealed that hydroelectricity intensified in short runs. However, during the longer time in USA, hydro energy diminished CO_2. Similarly, in another study Bilgili et al, (2016) indicated that biomass energy is a useful source of energy, which helps to reduce CO_2 and outcomes for the period from 1984 to 2015 confirmed biomass energy helps to achieve sustainable development path in US by reducing harmful gases.

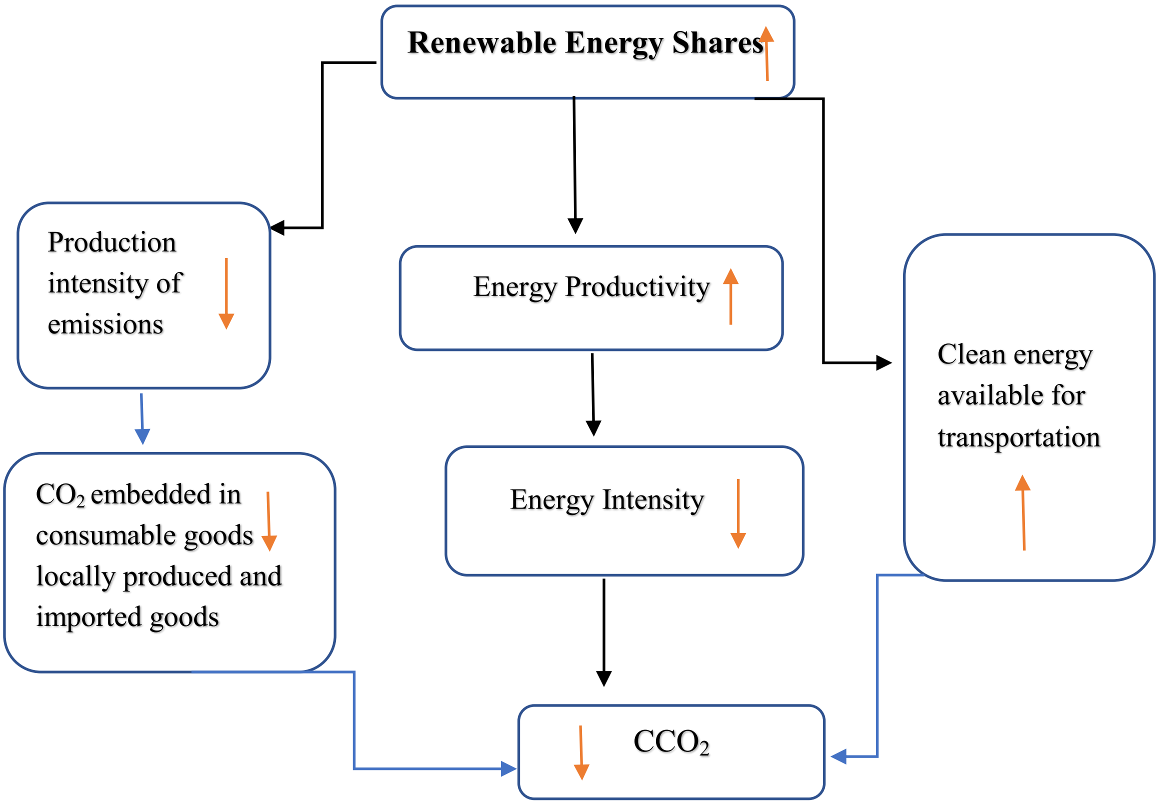
Study by Dogan and Inglesi-Lotz (2017) investigated twenty biomass energy consuming countries over the period 1985-2012 and showed potential of biomass energy to mitigate environmental degradation and supported EKC hypothesis by employing Fully Modified Ordinary Least Square technique.

Study by Majeed et al. (2022) on the role of biomass consumption, showed different income groups have different results of biomass to combat emissions. By employing the technique of FMOL, DOLS and Driscoll-Kray estimation, it is investigated that there exists long run relationship in between biomass energy and environmental indicator. Moreover, for high income group biomass energy has potential for emission reduction. However, upper-middle-income, lower-middle-income and low-income group are facing negative effect of biomass energy. Moreover, high and upper middle-income countries validated inverted U-shaped EKC while EKC is showed U-shaped curve for lower middle- and low-income countries.

Alternatively, Azam and Khan (2016) study opposed and supported the EKC hypothesis for low and lower middle-income countries while U-shaped EKC exists for high and upper-middle income countries. In contrast to these studies Solarin et al., (2018) by employing the method of GMM investigated eighty developed and developing countries and revealed biomass energy emits GHGs like carbon-dioxide while hydroelectricity decreases carbon emissions.

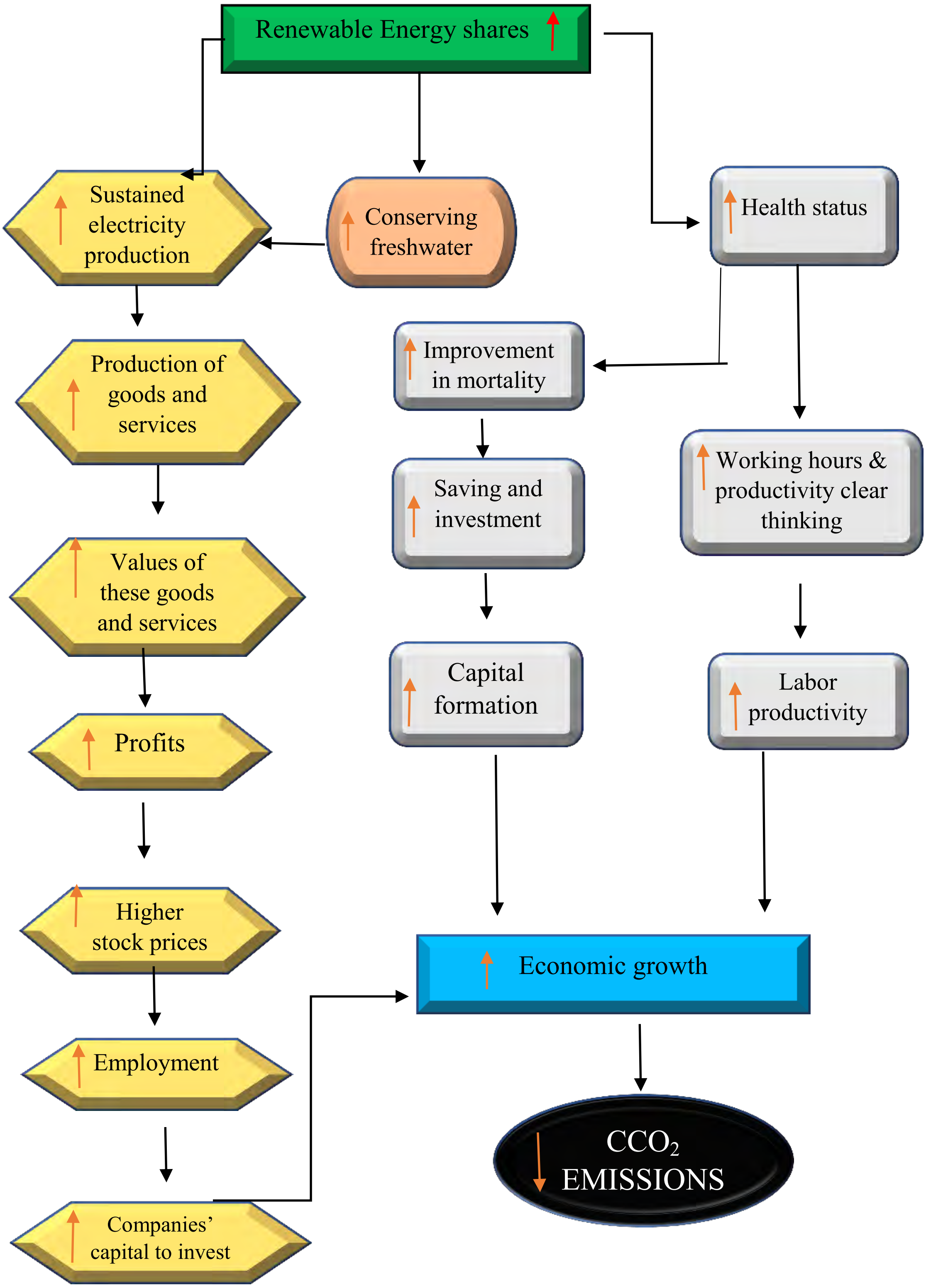
2.4. Graphical Literature

Figure 2.1: Linkage of Renewable energy with Sustainable environment



Source: Own Analysis

Figure 2.2: Channels linking Renewable Energy to Environmental Sustainability through Economic Growth



Kirikkaleli et al., (2022); Majeed et al., (2021) and Peter and Hertwich, (2008).

Chapter 03

Methodology

3.1. Introduction

The following chapter is providing detail about the methodology that has applied in analyzing the impact of GDP per capita and aggregated and disaggregated renewable energy on consumption-based emission accounting. First section of the chapter will formulate theoretical framework of model in investigation of GDP per capita and aggregated and disaggregated renewable energy role to determine consumption-based carbon emissions. This section will explain the present study model framework in the context of existing economic theories regarding environmental aspects. This section will also propose econometric modelling for present study. The second section will explain the detail regarding econometric methodologies that have applied on our proposed model. This study has used various econometric methods to investigate the relationship between dependent and independent variables, this chapter will discuss those techniques in detail.

3.2. Modelling Framework

3.2.1. Theoretical Modeling

The theoretical baseline model is based on EKC hypothesis proposed by Grossman and Krueger in 1991. The model used by Holtz-Eakin & seldon (1995), Bilgili et al. (2016), Pandey et al. (2020), Danish et al. (2022).

$$\text{Environmental degradation} = f\,(\text{GDP}, \text{GDP}^2)$$

With increasing environmental degradation and climate change the focus has been shifted from income to other factors that results in emissions because with growth there are other factors on which growth is dependent and without taking into account such factors the cost born will be, environmental degradation. To represent the development of the economies, growth is taken as an indicator. GDP per capita and square term of GDP per capita capture the nonlinear relationship between development and environmental degradation. To boost the economic growth energy is required. As energy serve the important role for the expansion of production activities which increase output and ultimately contribute to economic growth. Therefore, fossils fuel sources substitute by renewable and efficient sources to increase environmental quality.

Present study incorporated renewable energy at aggregate and disaggregate level for explaining that different sources of renewable energy enhance the quality of environment. Sources of renewable energy emits negligible amounts of carbon emissions (Saidi and Omri, 2020). Unlike conventional sources of energy (fossils fuels), renewable energy sources like solar and wind are inexhaustible.

present study incorporates the role of financial development in EKC hypothesis. Financial development can affect carbon emissions positively or negatively as it leads to greater loans to consumers and producers and increase purchasing power regarding energy consumable goods that increase carbon emissions. Financial development leads to greater loans to industries and lower cost of capital and accelerate new investment to clean technologies and increase or decrease carbon emissions. Financial development helps out to control environmental degradation by proving “green credit” by financing energy efficient technologies and in renewable energy.

This study also incorporates the energy intensity, as it shows the amount of energy that are using for production purposes. Higher energy intensity may increase CO_2 emissions if energy generation depends on fossils fuels. While, innovation of renewable technologies may help in reducing energy intensity.

With an increasing population, and lack of basic facilities in rural areas people migrate from rural to urban areas for the assessment of facilities like job, education, and medical facilities. Limited resources are available for urban population which lead to over exploitation of resources and environmental degradation. Urbanization leads to increasing demand for energy in transportation and electricity purposes that results in deteriorating environmental quality. This study also incorporated urbanization. The current study is considering consumption-based carbon emissions an indicator to measure environmental quality, by following studies in literature: (Danish et al., 2022 and Du et al., 2022). Thus, the functional form of the model is as follow:

Consumption-based carbon emissions=

f (GDP, GDP^2, Renewable Energy, financial development, energy intensity, gross fixed capital formation, urbanization) $_{it}$ (1)

3.2.2 Econometric Modelling

Arguments built in theoretical modelling mentioned in equation (1) can be converted into econometric models as follows

Model 1

$$\mathbf{CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 REC_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it}} \quad \textbf{(2)}$$

Where,

CCO_2 is Consumption-based carbon emissions. REC shows aggregate renewable energy consumption. GDP is GDP per capita and GDP^2 is used to capture the non-linear relationship between environmental degradation and economic development. All other variables FD (financial development), EINTS (Energy Intensity), GFCF (Gross Fixed Capital Formation) and URB (Urbanization) are used as control variables. α and ε_{it} are intercept and error term while u_{it} and v_{it} captures the unobserved country specific effects and temporal fixed effects respectively. Parameters β_1 to β_7 are slope coefficients, which measures the marginal effects of explanatory variables.

Additionally, to investigate the impact of different sources of renewable energy on consumption-based carbon emissions, renewable energy is disaggregated according to the sources used to generate electricity from renewable. Therefore, the following equations are used to investigate the relationship between disaggregated renewable energy and consumption-based carbon emissions.

Model 2

$$\mathbf{CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELES_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it}} \quad \textbf{(3)}$$

Model 3

$$\mathbf{CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEW_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it}} \quad \textbf{(4)}$$

Model 4

$$CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEB_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it} \quad (5)$$

Model 5

$$CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEH_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it} \quad (6)$$

Model 6

$$CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEG_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_{it} + v_{it} + \varepsilon_{it} \quad (7)$$

Where,

ELES shows electricity generation from solar energy, ELEW shows electricity production from wind energy, ELEB shows electricity production from biomass and waste, ELEH hydroelectricity and ELEG shows electricity generation from geothermal energy respectively.

All of these six models play crucial role in achieving the objective of our study.

3.3. Econometric Techniques

To explore the validation of EKC hypothesis and to find out the impact and link between aggregated and disaggregated renewable energy with consumption-based carbon emissions present study has used panel data. Panel data consists of quantitative and qualitative information about variables both across cross sectionally "N" and over time period "T". Present study will employ econometric techniques that are specific for panel data to get objective of the study. Traditional econometric techniques for panel data set are pooled OLS, random effects and fixed effects that are applied on static models. Present study will employ these techniques along Driscoll and Kray regression method. This study also employed System Generalized method of moments (SGMM) on dynamic panel data set. Moreover, specific test applied for the selection of best possible technique are also explained. Next sections will provide detail explanation about these econometric techniques.

3.3.1. Traditional Econometric Techniques of Panel Data

Pooled OLS technique

In panel data analysis, first of all pooled OLS technique will be utilized for the estimation of regression equations. Pooled OLS technique will provide the general picture of relationship between non-linear relationship between GDP per capita and consumption-based carbon emissions and aggregated and disaggregated renewable energy on consumption-based carbon emissions. Pooled OLS techniques assume constant intercept for all entities which means all countries are homogenous. In Pooled OLS technique, the regression equations will be taking following forms:

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 REC + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(8)}$$

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 ELES + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(9)}$$

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 ELE \quad W + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(10)}$$

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 ELEB + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(11)}$$

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 ELEH + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(12)}$$

$$\mathbf{CCO_2 = \alpha + \beta_1 GDP + \beta_2 GDP^2 + \beta_3 ELEG + \beta_4 FD + \beta_5 EINTS + \beta_6 GFCF + \beta_7 URB + \varepsilon} \qquad \mathbf{(13)}$$

If all assumptions hold for regression models than all independent variables in the above models yields consistent outcomes. On the other hand, violation of the regression model's assumptions creates issues of heterogeneity, autocorrelation, multicollinearity and endogeneity that will bring inefficient outcomes of pooled OLS regression. Estimators of pooled OLS regression consider all cross-sectional units are independent and homogeneous that assumes intercept and slopes are identical. However, error terms of the countries may correlate over time and assumption may not hold. Therefore, due to the limitations of pooled OLS regression models we also applied random and fixed effects models.

Fixed effects technique

Fixed effects model assumes all countries in the panel data set are heterogenous. These heterogeneity in the countries due to the specific characteristics present in each country. Fixed effect models capture all unobserved specific characteristics that do not vary over time. The differences in countries captured by differences in intercept term in fixed effect models thar is also called Least Square dummy variables (LSDV). The regression equations will be taking following forms under fixed effect models:

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 REC_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \qquad \mathbf{(14)}$$

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELES_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \qquad \mathbf{(15)}$$

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEW_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \qquad \mathbf{(16)}$$

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEB_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \qquad \mathbf{(17)}$$

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEH_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \quad \mathbf{(18)}$$

$$\mathbf{CCO_{2it} = \alpha_i + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEG_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + \varepsilon_{it}} \quad \mathbf{(19)}$$

Where α_i is indicating the unobserved individual specific effects which do not vary over time. This intercept term by capturing country specific effect is changing for each cross-sectional entity. However, fixed effects are more efficient technique than pooled OLS but it does not catch the time invariant characteristics of the models. Furthermore, this technique has another drawback of loss of degree of freedom.

Random Effects Techniques

Another technique that is used for panel effects models is random effects models. This technique treats individual effects as random rather than a fixed by assuming there is zero correlation between individual terms. Moreover, individual terms are independent over time and cross-sectional. The regression equations will be taking following forms under random effect models:

$$\mathbf{CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 REC_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(20)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELES_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(21)}$$

$$\mathbf{CCO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEW_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(22)}$$

$$\mathbf{CCO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEB_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(23)}$$

$$\mathbf{CCO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEH_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(24)}$$

$$\mathbf{CCO_{2it} = \beta_0 + \beta_1 GDP_{it} + \beta_2 GDP^2_{it} + \beta_3 ELEG_{it} + \beta_4 FD_{it} + \beta_5 EINTS_{it} + \beta_6 GFCF_{it} + \beta_7 URB_{it} + u_i + \varepsilon_{it}} \quad \mathbf{(25)}$$

Random effect model as compared to fixed effect model has more degree of freedom. This technique is better option if the explanatory variables independent and not correlated with country specific error term. On the other side, if there is existence of correlation than fixed effect model is more preferred than random effect model (Gujrati, 2012).

Breusch and Pagan LM Test

For the selection of best technique for estimation some specific tests are applied. To choose the better technique between pooled OLS and panel effects Breusch and Pagan LM test is applied. Hypothesis of the test are as following:

H_0 = There are no difference across units (i.e., no Panel effect or Pooled is better)

H_1 = There are differences across units (i.e., Random effects is better)

Above mention hypothesis is tested by LM test. If probability value of chi square is less than 0.05 than null will be rejected and preferred model is random effect model.

Hausman Test

To select the better technique between panel effects models i.e., Fixed effect or random effect Hausman test is applied. The idea behind it is that under the null hypothesis of no autocorrelation, both OLS in fixed and random is consistent Greene (2003). Hausman is applied to be test the null hypothesis as following:

H_0: Differences in Coefficients are not systematic (Random effect is preferred)

H_1: Differences in Coefficients are systematic (Fixed effect is preferred model)

The differences among the coefficients showing the differences between random and fixed effects. If probability value of chi square is less than 0.05 than null will be rejected and preferred model is fixed effect model.

Driscoll and Kray Regression

Traditional models will indicating inconsistent outcomes if specific assumption of classical linear regression models violated. Moreover, the presence of autocorrelation, heteroskedasticity and cross-sectional dependency creates issues in models' outcomes. There is need to address these problems. Therefore, in this regard pooled OLS, random effects and fixed effects are estimated by taking into account autocorrelation, heteroskedasticity and cross-sectional dependency issues. Then applying the panel Driscoll and Kray (1998) regressions that is robust panel data method which provides consistent estimators. These regression analyses generate robust standard errors in the existence of autocorrelation and heteroskedasticity.

Although, Driscoll and Kray (DK) regressions tackle cross-sectional dependency, heteroskedasticity and autocorrelation but this technique do not tackle the problem of endogeneity in the models. Therefore, we also applied generalized method of moments (GMM) to tackle the issue of endogeneity.

3.3.2. System Generalized Method of Moments (SGMM) technique

To tackle the problem of endogeneity in the models, generalized method of moment is best and advance technique. The present study is following the estimators proposed by Blundell and Bond and Arellano and bond (1998) which is known as SGMM. This technique is helpful to address all types of endogeneity and provide more effective outcomes.

The regression equations will be taking following forms under SGMM:

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 REC_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(26)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 ELES_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(27)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 ELEW_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(28)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 ELEB_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(29)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 ELEH_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(30)}$$

$$\mathbf{CCO_{2it} = \alpha + \beta_1 CCO_{2i,t-1} + \beta_2 GDP_{it} + \beta_3 GDP^2_{it} + \beta_4 ELEG_{it} + \beta_5 FD_{it} + \beta_6 EINTS_{it} + \beta_7 GFCF_{it} + \beta_8 URB_{it} + \eta_i + \mathit{v}_{it}} \quad \mathbf{(31)}$$

In this technique lagged of CCO_2 is also included as a regressors of dependent variable. Therefore, lagged dependent variables of CCO_2 is also part of the model as an independent variable. In above equations, β_1 is the slope coefficient of lagged dependent variable and η_i is the country specific effects and v_{it} is error term.

To estimate the relationship between independent and dependent variables this approach is more effective as compared to traditional techniques. Firstly, this approach is helpful to handle the model if model is suffering with endogeneity. Secondly, inclusion of lagged dependent variable provide more best estimates than traditional techniques. Thirdly, it also tackles the issue of reverse causality in the models. Forth, under SGMM estimators use both variations, between country variations and over time variations (Arellano and Bover, 1995).

SGMM consists of two sets of equations. First set is first difference equation that is instrumented with lagged variables while second set is level equation that is instrumented with first difference lagged variables. Effectiveness of this technique is based on validity of instruments and correlation analysis of residuals. Two specification test Hansen J-test and Arellano-bond test are proposed for the appropriation of SGMM (Arellano and Bond, 1995).

Hansen J-test

To test the validation of instrumented variables used in the model Hansen j-test is reported along the regression estimation in SGMM. This test is applied to check the over identification restriction of instrumented variables. This tests the following hypothesis:

H_0: Instruments are valid

H_1: Instruments are not valid

Based on less than 5% p-value, null hypothesis will reject the validation of instruments.

Arellano-bond Test

To test the second order serial correlation between residuals another specification test is reported in SGMM along the regression outcomes. This test is known as Arellano-Bond test and it is tested the following hypothesis:

H_0: Residuals are serial uncorrelated

H_1: Residuals are serial correlated

Based on probability value of chi-square less than 0.05 null will reject, that residuals are serial uncorrelated. Acceptance of both tests will assure the effectiveness of SGMM approach.

Chapter 04

Data and Variables Description

4.1. Introduction

This chapter will elaborate comprehensive detail about nature of the data and sample. Further it will also explain how data is divided into sub-samples. Moreover, variable description is also included in this chapter. It will report the definitions, sources and units of variables used in the model.

4.2. Data and variables Description

4.2.1. Data Type

For empirically revealing the impact of aggregate and disaggregated renewable energy on consumption-based carbon emissions the study is analyzing panel data set which is also named as "longitudinal data". Panel data refers to the data incorporating time-series analysis and cross-sectional analysis together. Present study is focusing on panel data analysis due to merits of panel data over cross sectional and time series analysis. Panel data set provide more comprehensive information than cross-sectional and time series analysis. As it is filled with the information about individuality of cross sections and intertemporal dynamics thus, help out in controlling the impact of missing observations. As compared to cross-sectional and time-series, Panel data contains more degree of freedom, intensify sample set variability as compared to cross-sectional and time series set of data. Thus, it is improving the efficiency of estimates (Hsia, 2007). As it is filled with the information about individuality of cross sections and intertemporal dynamics thus, help out in controlling the impact of missing observations. Moreover, it also controlling the omitted variables impact.

Additionally, due to large sample there is less chance of creating issue of multicollinearity in panel data set. Concerning these merits this study prefers panel data set for analyzing the impact of aggregat and disaggregated renewable energy on consumption-based carbon emissions.

4.2.2. Data Sample

Initially, to estimate the impact of aggregated and disaggregated renewable energy on consumption-based carbon emissions, data for 217 countries are taken into consideration. But the data series were missing for dependent variable and some independent variables, therefore, final sample size is selected for 107 countries. Moreover, data for all variables is taken over time period of 1990-2021.

This study also divided final sample into further sub-samples of net-importers of carbon emissions and net-exporters of carbon emissions. Sub-samples are based on ratio and differences between CCO_2 and PCO_2. These ratios and differences are obtained by taking average values of CCO_2 and TCO_2 for each country from 1990 to 2021. Net-importers of carbon emissions are those countries in which CCO_2 is greater than TCO_2 and net-exporters of carbon emissions are those countries in which TCO_2 is greater than CCO_2 (See Appendix).

4.2.3. Variables Description

To achieve the objectives of the study different variables is used in the model. Data is comprising of consumption-based carbon emissions as dependent variable to measure environmental quality, Renewable energy as core variable of interest on right hand side, while for the validation of EKC variable of economic growth is used. Other variables financial development, energy intensity, capital stock and urbanization are used as control variables.

4.2.3.1 Dependent Variable

Consumption-based carbon emissions

The study has treated consumption-based carbon emissions as a dependent variable to measure the environmental sustainability. Data for response variable is extracted from Global Carbon Atlas (GCA-2021). It is measured as million tons (mt) total annual. According to Our World in Data (2020) "Consumption-based carbon emissions are national emissions that have been adjusted for trade. It calculated by including all carbon emissions that were emitted in the production of imported goods and services and excluding all carbon emissions that were emitted in the production of exported goods and services from total carbon emissions within a country. This measures fossils fuels and industry emissions; Land use change is not included". Recently, Empirical literature is presenting studies utilizing CCO_2 as a measure of environmental sustainability. This variable has been used by Knight (2014), Wiebe (2016), Khan et al. (2020), Bhattacharya et al. (2020), Ding et al. (2021), Kirikkaleli and Adebayo (2021), Danish et al. (2022) and Du et al. (2022). For estimation purpose log form of CCO_2 is utilized. Dependent variable is transformed into log form for econometric analysis.

4.2.3.2 Independent Variables

The analysis compiles following focus and control variables for estimating the derived regression equation:

Renewable Energy (Aggregated and Disaggregated)

Main focus of this study is to test the role of different sources of renewable energy on consumption-based carbon emissions. Thus, renewable energy is treated as focus variable among all regressors. This study is using aggregated and disaggregated renewable energy. To accounts the impact of aggregate renewable energy on dependent variable, we are using the overall renewable energy consumption in regression model measured as percentage of total final energy consumption. “It refers to aggregate share of energy sources like solar, wind, biomass and biofuels, geothermal and hydro etc. in total final energy consumption”. The data for aggregate renewable energy is extracted from World development indicator (WDI-2022).

To access the role of renewable energy at disaggregate level, the renewable energy is segregated according to the electricity generation from different sources of renewable energy. First proxy is the electricity generated from Solar energy measured in billion kilowatt-hours (kwh). “It refers to electricity generated from Solar energy through Photovoltaics Solar panels and Solar thermal power plants.” Second proxy is electricity generated from Wind energy measure as billion kilowatt-hours (kwh). “It refers to generate electricity from Wind energy through Wind turbines.” Third proxy is electricity generated from Biomass and Waste also measured in billion kilowatt-hours (kwh). “It refers to electricity generation from combustion of biomass materials such as agricultural waste or woody materials.” Forth proxy is hydroelectricity measured as billion kilowatt-hours (kwh). “It refers to electricity generation by uses of hydro power plants.” Fifth proxy is electricity generation from geothermal energy measured as billion kilowatt-hours (kwh). “It refers to the electricity generated from geothermal energy through geothermal power, e.g., flash steam power station, binary cycle power station and dry steam power station.” Data for disaggregate renewable energy into Solar, Wind, Biomass and waste, Hydroelectricity and Geothermal energy series is extracted from Energy Information Administration (EIA-2022).

Empirical studies are mainly suggesting positive role of renewable energy to mitigate environmental degradation and its effectiveness to enhance environmental sustainability. Electricity generated from renewable sources emits less carbon emissions. Increase in renewable sources replace carbon intensive sources of energy. Therefore, it decreases the emission intensity of production processes and goods demanded by consumer locally and internationally embedded with less amount of carbon emissions, finally reduces the consumption-based carbon emissions. Empirical studies investigated the impact of REC on environmental sustainability (Balsalobre-Lorente et al., 2017; Sinha and Shahbaz., 2018; Majeed and Luni., 2019; Saidi and Omri., 2020; Destek and Aslan., 2020 and Sahoo and Sahoo., 2022). Recently, studies have focused the association between REC and CCO_2 (Khan et al., 2020; Kirikkaleli et al., 2021; Du et al., 2022 and Danish et al., 2022). All variables of renewable energy (aggregated and disaggregated are transformed into log form.

Economic Growth

Economic growth is an important determinant of environmental indicators. To analyze the EKC curve for the model the present study has used variable of economic growth as an explanatory variable. For economic growth, the proxy of GDP per capita is used. As economic growth may twofold impact on environmental indicators therefore, GDP per capita square is also incorporated in the model. GDP per capita is measured as constant prices 2015 which is expressed in unit of US dollars. Data is extracted from WDI-2022. According to WDI "GDP per capita is gross domestic product divided by midyear population of a country. It is measured by deduction of fabricated assets and depletion and degradation of natural resources." Empirical literatures have used this proxy as a measure of economic growth. Previous study widely used GDP per capita for analyzing the income-pollution relationship. Empirical studies mainly suggesting twofold impact of GDP per capita on CCO_2. They argue that initially, when income rises emissions increased because of increased in economic activities that required intensive used of energy for production and consumption purposes. But after reaching higher level of income emissions start falling gradually due to utilization of clean energy sources and changes in consumer's preferences. Numerous studies used GDP per capita for empirical analysis including Farhani and Shahbaz (2014); Majeed and Luni., (2019); Khan et al., (2020); Shahbaz et al., (2021); Danish et al., (2022). Variables of GDP per capita and square of GDP per capita are transformed into log form for estimations.

Financial Development

Financial development (FD) is an important macroeconomic indicator which influence consumption-based carbon emissions. Different studies indicated different results regarding role of FD on environmental indicator. Some previous studies argue in favoring of beneficial effect of FD to achieve environmental quality. They explained that well developed financial system brings up research and development projects in clean resources and investment in sustainable energy technologies and renewable energy technologies like photovoltaic and wind turbines. Moreover, development in financial sectors also lower financial cost and capital risks and paly important role to improve economic efficiency. Further arguments in favoring of financial development that it also broadening the financial, banking and capital activities and FDI inflows that encourage the investment in clean resources of energy (Shahbaz et al., 2013; Majeed and Mazhar, 2019; Khan and Ozturk, 2021 and Kirikkaleli et al., 2022). While some studies depict that FD shows harmful role on environmental indicators. They argue that development in financial sectors provide greater consumer loans that encourage the consumer's purchasing power for electrical appliances, automobiles and houses that required intensive energy. Moreover, credit facilities to investors motivate their purchasing power regarding machineries that utilized energy to perform functions and investors expand their businesses builds new offices that required electricity. Thus, financial development may increase the environmental deterioration (Baloch et al., 2019; Jian et al., 2019 and Lu and Li, 2021).

This study is also incorporating financial development as a control variable by considering the importance regarding its role on environmental indicators. Domestic credit to private sector is used for the proxy of financial development that is measure as percentage of GDP. The data has been collected from WDI-2022. According to WDI-2022 “It refers to financial resources given to the private sector by financial corporation, such as through loans, purchases of non-equity securities and trade credits.” Literature is reporting this proxy as a measure of financial development (Jian et al., 2019; Majeed and Mazhar 2019; Baloch et al., 2021 and Khan and Ozturk, 2021). Variable of financial development is transformed into log form for econometric analysis.

Energy Intensity

Another regressor after financial development included in econometric analysis is energy intensity. It is most important indicator in determining the environmental sustainability. Abundant of studies have used energy intensity in econometric analysis as a major determinant of environmental degradation. Previous studies revealed that energy intensity has negative role on environmental sustainability (Roca and Alcantara, 2001; Shahbaz et al., 2015; Xu et al., 2016; Ulucak et al., 2020 and Shokoohi et al., 2022). Current study is also incorporated energy intensity as a control variable in the models. it measures as megajoule per US$ PPP GDP. Data for this variable is extracted from WDI-2022. According to WDI “It refers to energy intensity is the ratio between the energy supply and gross domestic product. Lower ratio implies that less units of energy are used to produce one unit of economic output." variable of energy intensity is converted into log form for estimations.

Gross Fixed Capital Formation

To account the role of capital stock on carbon emissions, we use gross fixed capital formation, it measures as (constant 2015 US dollars). In Gross fixed capital formation, fixed assets like machinery, land improvements, plants, and equipment's purchases, and infrastructure, building for public and private use are included." Data for the GFCF is collected from WDI-2022. Same variable is used by Abbas et al.,2020. This variable is used in log form for estimation.

Urbanization

To account the impact of urban population on CCO_2 this study used indicator of urban population measured in millions. "It refers to population in urban areas." Data has been extracted from WDI-2022. Migration from rural to urban population put pressure on resources. Houses, offices, vehicles and other regular consumable items demand increase, that indirectly increase the production activities. Moreover, consumption of transportation and electricity increase emissions. Therefore, previous studies used this variable as an important determinant of carbon emissions (Sadorsky, 2014; Shahbaz et al., 2016; Wang et al., 2018 and Yao et al., 2021). Variable of urbanization is used with log form for the econometric analysis.

Table 4.1: Data Description

Variables	**Abbreviations**	**Units**
Consumption-base Carbon emissions	CCO_2	Million tons
GDP per capita	GDP	Constant 2015 US $
GDP per capita square	GDP^2	Constant 2015 US $
Renewable Energy Consumption	REC	% Of total energy
Electricity from Solar	ELES	Billion kilowatt-hours
Electricity from Wind	ELEW	Billion kilowatt-hours
Electricity from Biomass	ELEB	Billion kilowatt-hours
Hydroelectricity	ELEH	Billion kilowatt-hours
Electricity from Geothermal	ELEG	Billion kilowatt-hours
Financial Development	FD	% Of GDP
Energy Intensity	EINTS	Mega joule / US $ PPP GDP
Gross Fixed Capital Formation	GFCF	Constant 2015 US $
Urbanization	URB	Millions

Chapter 05

Statistical and Graphical Analysis

5.1. Introduction

This chapter will document the most important step of data analysis. This chapter comprises of two sections. First section will discuss the statistical characteristics of variables that have used in current study. It analyzes the data by providing summary statistics and correlation matrix. Second section of chapter will illustrate the graphical information. It provides the graphical analysis of data at global level along with comparison between net-importers and net-exporters of emission countries.

5.2. Statistical Analysis of Data

Coming section will illustrate the statistical analysis applied on data. The section is divided into two segments. First section will report and explain the descriptive statistics while second segment will explain the correlation analysis of variables.

5.2.1. Descriptive Statistics

Descriptive statistics comprises of global data is revealing valuable information about central tendency and measures of dispersion including number of observations, mean, standard deviation, maximum and minimum value of each variable. This summary statistics of global data is in table 5.1 (a). According to the outcomes of descriptive analysis, data covering CCO_2 is reporting total observation of 3496. The average value of CCO_2 229.1136 million tons. However, its minimum and maximum value is obtained -1.4109 million tons and

9442.84 million tons respectively. This highest CCO_2 is recorded in China and lowest CCO_2 is recorded in Panama.

Regarding core variables of interest i.e., aggregate renewable energy, data covering total observations of 3504 and average value is 30.80 percent of total final energy consumption. Maximum value of aggregate renewable energy is reported to be 97.74 percent of total final energy consumption belonging to the state of Ethiopia while minimum value is 0.0090 percent of total final energy consumption which belongs to Saudi Arabia. Descriptive analysis of different sources of renewable energy is also performed as presented in table 5.1 (a). According to the outcomes, average value of 1.269, 3.519, 2.573, 26.225 and 0.486 billion-kilowatt hour is disclosed for electricity generated from solar, wind, biomass, hydroelectricity and geothermal respectively. The highest value of electricity generation from solar, wind, biomass and hydroelectricity are reported in China with a magnitude of 326.437, 611.221, 136.434 and 1321.51 billion-kilowatt hour respectively. Likewise, highest value of electricity generation from geothermal energy is reported as 16.788 billion-kilowatt hour for USA. Whereas minimum value for electricity generated from solar, wind, biomass, hydroelectricity and geothermal is reported in Bangladesh, Mongolia, UAE, Benin and Austria with a magnitude of 0.00002, 0.00001, 0.0001, 0.00006 and 0.00002 billion-kilowatt hour respectively. Additionally, it can be inferred that hydroelectricity is growing relatively higher than electricity generation from solar, wind, biomass and geothermal energy on average.

Similarly, summary statistics is also conveying information about other regressors. For instance, data covering GDP per capita is reporting total observation of 3649. The average value of GDP is 14599.7 constant 2015 US $.

However, its minimum and maximum value is obtained 204.024 constant 2015 US $ and 14599.7 constant 2015 US $. Similarly, average value for FD is reported as 55.647 (% of GDP) while minimum and maximum value is recorded as 0.1862 for Slovenia and 258.949 for Hongkong. Moreover, on average 1.06e+11 constant 2015 US $ of capital is accumulated across the world. Highest level of capital is 4.66e+12 constant 2015 US $ while its lowest value is 4.75e+07 constant 2015 US $. Average value for energy intensity is reported as 5.2298 megajoule per US $ PPP GDP. Whereas minimum and maximum values are 1.31 and 26.91 megajoule per US $ PPP GDP respectively. Average value of urban population in million is recorded as 2.57e+07. Minimum and maximum value is recorded for Brunei Darussalam and China that is 171884 and 8.83e+08 respectively.

Table 5.1 (a): Descriptive Statistics (Global Data)

Variables	**obs.**	**Mean**	**Std. Dev**	**Minimum**	**Maximum**
CCO2	3496	229.1136	792.3726	-1.4109 (Panama)	9442.835 (China)
GDP	3649	14599.7	18850.74	204.024 Mozambique	112417.9 (Luxembourg)
REC	3504	30.80616	29.2119	0.0090 Saudi Arabia	97.7404 (Ethiopia)
ELES	3605	1.2691	10.9051	0.00002 (Bangladesh)	326.4374 (China)
ELEW	3605	3.5195	23.7081	0.00001 (Mongolia)	611.2206 (China)
ELEB	3602	2.5734	9.5598	0.0001 (UAE)	136.4338 (China)
ELEH	3608	26.2251	85.4098	0.00006 (Benin)	1321.511 (China)
ELEG	3605	0.4866	2.0242	0.00002 (Austria)	16.7885 (USA)
FD	2762	55.6477	46.8076	0.1862 (Slovenia)	258.9492 (Hong Kong)
EINTS	2336	5.2298	3.0823	1.31 (Hong Kong)	26.91 (Mozambique)
GFCF	3175	1.06e+11	3.45e+11	4.75e+07 (Rwanda)	4.66e+12 (China)
URB	3740	2.57e+07	7.02e+07	171884 Brunei Darussalam	8.83e+08 (China)

Table 5.1 (b): Descriptive Statistics (Net-importers of Carbon Emissions)

Variables	Obs.	Mean	Std. Dev	Minimum	Maximum
CCO2	2,536	175.8368	660.94	-1.4109	6618.792
GDP	2,676	15684.33	20349.61	204.0242	112417.9
REC	2,544	36.1551	28.989	0.05	97.7404
ELES	2,618	1.0371	7.0475	0.00002	163.7028
ELEW	2,618	3.1880	18.2910	0.00001	379.7672
ELEB	2,616	2.8018	9.3994	0.0001	77.6597
ELEH	2,620	23.553	62.2805	0.00006	424.05
ELEG	2,618	0.5852	2.2061	0.00002	16.7886
FD	1,983	58.190	49.581	0.186	258.95
EINTS	1,700	4.6098	2.7459	1.31	26.91
GFCF	2,417	1.13e+11	3.78e+11	1.99e+08	4.25e+12
URB	2,720	1.72e+07	3.45e+07	309096	2.75e+08

Table 5.1 (c): Descriptive Statistics (Net-exporters of Carbon Emissions)

Variables	obs.	Mean	Std. Dev	Minimum	Maximum
CCO2	900	394.4251	1081.778	3.0335	9442.835
GDP	910	12380.6	13618.1	527.5145	65129.38
REC	900	12.1345	18.0634	0.009	88.68
ELES	926	2.0081	17.9448	0.00007	326.4374
ELEW	926	4.6886	35.2267	0.00001	611.2206
ELEB	925	2.0971	10.2622	0.001	136.4338
ELEH	927	35.4773	131.5094	0.016	1321.511
ELEG	926	0.2398	1.4462	0.0004	15.563
FD	719	52.511	37.798	4.957	182.86
EINTS	596	6.9146	3.4022	2.38	21.6
GFCF	713	8.70e+10	2.05e+11	9.66e+08	4.66e+12
URB	957	5.14e+07	1.22e+08	171884	8.83e+08

Additionally, summary statistics on the basis of net-importers and net-exporters of emission countries sample is also provided in table 5.1 (b) and 5.1 (c) respectively. According to outcomes net-exporters of carbon recording highest CCO_2 of 9442.835 million tons as compared to net-importers of carbon countries 6618.792 million tons.

Moreover, data is suggesting highest GDP per capita of 112417.9 constant 2015 US $ belongs to net-importers of emission countries as compared to net-exporters of emission countries reporting 65129.38 constant 2015 US $. Moreover, according to data outcomes net-exporters of carbon emission countries recording highest electricity generated from solar energy, wind energy, biomass energy and hydroelectricity of 326.4374, 611.2206, 136.4338 and 1321.511 respectively as compared to net-importers of carbon emission countries reporting 163.7028, 379.7672, 77.6597 and 424.05 respectively. similarly, descriptive statistics of other variables are also reported in table 5.1 (b) and 5.1 (c).

5.2.2 Correlation Analysis

Correlation matrix presented in table 5.2 (a) is showing the relationship between aggregated and disaggregated renewable energy and CCO_2 along with other regressors in case of global sample. Correlation values are mentioned in correlation matrix that determine the relationship between variables. Aggregate renewable energy has negative correlation with consumption-based carbon emissions while disaggregating sources of renewable energy according to electricity generation than, all sources (solar, wind, biomass, geothermal and hydroelectricity) have positive correlation with CCO_2. However, the correlation between hydroelectricity and consumption-based carbon emissions is relatively high (0.8315). Economic growth, financial development, Energy intensity, Gross fixed capital formation and Urbanization also possesses positive correlation with consumption-based carbon emission.

Table 5.2 (a): Correlation Matrix (Global Data)

	LCCO2	*LGDP*	*LGDP2*	*LREC*	*LELES*	*LELEW*	*LELEB*	*LELEH*	*LELEG*	*LFD*	*LEINTS*	*LGFCF*	*LURB*
LCCO2	1												
LGDP	0.5688	1											
LGDP2	0.5661	0.9986	1										
LREC	-0.8486	-0.6086	-0.596	1									
LELES	0.5476	0.5631	0.5673	-0.433	1								
LELEW	0.3662	0.3333	0.3352	-0.321	0.7135	1							
LELEB	0.7507	0.5320	0.5306	0.6226	0.7766	0.5759	1						
LELEH	0.8315	0.6638	0.6599	0.7180	0.4681	0.3936	0.4616	1					
LELEG	0.2132	-0.2218	-0.222	-0.159	-0.128	-0.0865	-0.116	0.2360	1				
LFD	0.4394	0.7300	0.7345	-0.408	0.5806	0.5966	0.5058	0.5013	-0.227	1			
LEINTS	0.2462	-0.169	-0.149	-0.218	0.0261	-0.2654	0.1118	0.1213	0.0241	0.0760	1		
LGFCF	0.9434	0.6132	0.608	-0.361	0.4345	0.4619	0.7098	0.5845	0.1827	0.5104	0.1561	1	
LURB	0.8020	0.2214	0.218	-0.721	0.4302	0.1707	0.5403	0.5767	0.4432	0.1574	0.2917	0.7739	1

Table 5.2 (b): Correlation Matrix (Net-importers of carbon emissions)

	LCCO2	***LGDP***	***LGDP2***	***LREC***	***LELES***	***LELEW***	***LELEB***	***LELEH***	***LELEG***	***LFD***	***LEINTS***	***LGFCF***	***LURB***
LCCO2	1												
LGDP	0.6813	1											
LGDP2	0.6855	0.9986	1										
LREC	-0.892	-0.658	-0.649	1									
LELES	0.6227	0.5553	0.5634	-0.456	1								
LELEW	0.5839	0.3949	0.3921	-0.465	0.7519	1							
LELEB	0.8214	0.5688	0.5701	-0.693	0.7784	0.7477	1						
LELEH	0.8540	0.2624	0.2566	-0.719	0.5321	0.5440	0.6915	1					
LELEG	0.2736	-0.213	-0.215	-0.264	-0.016	-0.078	-0.061	0.2198	1				
LFD	0.5016	0.7742	0.7844	-0.463	0.5491	0.6693	0.6667	0.6117	-0.07	1			
LEINTS	0.1775	-0.181	-0.147	-0.073	-0.008	-0.193	0.1238	0.0457	0.2431	0.0443	1		
LGFCF	0.9611	0.6952	0.6961	-0.417	0.6619	0.6251	0.7423	0.5543	0.2249	0.5647	0.1299	1	
LURB	0.7758	0.3676	0.3714	-0.806	0.5580	0.4191	0.6340	0.5196	0.4974	0.2456	0.2653	0.7630	1

Table 5.2 (b): Correlation Matrix (Net-exporters of carbon emissions countries Data)

	LCCO2	***LGDP***	***LGDP2***	***LREC***	***LELES***	***LELEW***	***LELEB***	***LELEH***	***LELEG***	***LFD***	***LEINTS***	***LGFCF***	***LURB***
LCCO2	1												
LGDP	-0.029	1											
LGDP2	-0.046	0.9991	1										
LREC	-0.584	-0.557	-0.533	1									
LELES	0.0402	0.6236	0.6041	-0.355	1								
LELEW	-0.018	0.1158	0.1298	-0.169	0.8224	1							
LELEB	0.0802	0.2606	0.2336	-0.202	0.7821	0.5920	1						
LELEH	0.9602	0.1082	0.0894	-0.743	0.0663	-0.029	0.0521	1					
LELEG	0.4841	-0.638	-0.627	0.1048	-0.692	-0.615	-0.534	0.3880	1				
LFD	-0.354	0.5673	0.5526	-0.062	0.4340	0.6927	0.6950	-0.312	-0.727	1			
LEINTS	0.5134	0.3065	0.2734	-0.810	0.3349	0.0837	0.2579	0.6410	-0.261	0.2414	1		
LGFCF	0.7924	0.3104	0.3139	-0.390	0.1629	0.3515	0.0429	0.6681	0.3219	-0.196	0.1441	1	
LURB	0.7512	-0.626	-0.628	0.0076	-0.427	-0.423	-0.213	0.6114	0.5873	-0.726	-0.006	0.5141	1

The study also presented the correlation matrix for data variables that are used in study on the basis of sample of net-importers of carbon emissions and net-exporters of carbon emissions. Outcomes of analysis are displayed in the table 5.2 (b) and 5.2 (c).

5.3. Graphical Analysis of Data

In this section we have illustrated the graphical analysis of our selected panel data. First section containing scatter plot depicting relationship between GDP per capita and CCO_2 while next section shows the relationship between aggregate and disaggregated renewable energy and Consumption-based carbon emissions.

5.3.1. Relationship Between Economic Growth and Consumption-based Carbon Emissions

This sub-section of graphical analysis shows the scatter plot relating response variable consumption-based carbon emissions and variable of GDP per capita. The analysis is further divided into two parts. First part presents the relationship between variables by considering overall data of variables for each country. While second part shows the relation between variables by considering average values of described variables for each cross sections.

5.3.1.1. Whole Data Analysis (Scatter Plot)

This part of graphical analysis indicates the relationship in between GDP per capita and CCO_2 by taking all data values of described variables. Scatter plot presenting in figure 5.1 shows the existence of EKC in case of global data for. The curve is predicting concave quadratic relationship in between GDP per capita and consumption-based carbon emissions for global data.

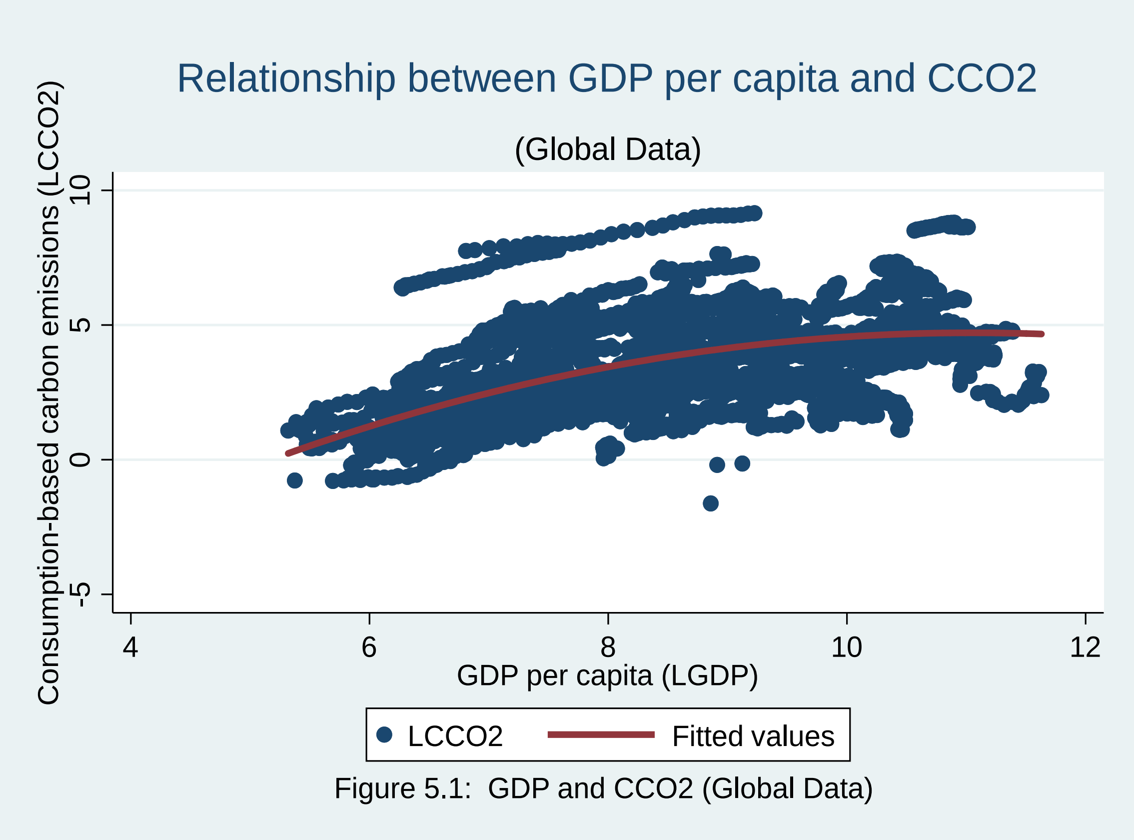


Figure 5.1: GDP and CCO$_2$ (Global Data)

The graph shows that initially scale effect dominates because consumption-based carbon emissions is rising along with increase in GDP per capita. After reaching threshold level, technique effect dominates because consumption-based carbon emissions are reducing along increase in GDP per capita.

5.3.1.2. Mean Value Analysis (Scatter Plot)

This part of graphical analysis indicates relationship in between GDP per capita and CCO$_2$ on the basis of average values. Mean analysis in figure 5.2 is supporting concave quadratic relationship between GDP per capita and consumption-based carbon emissions.

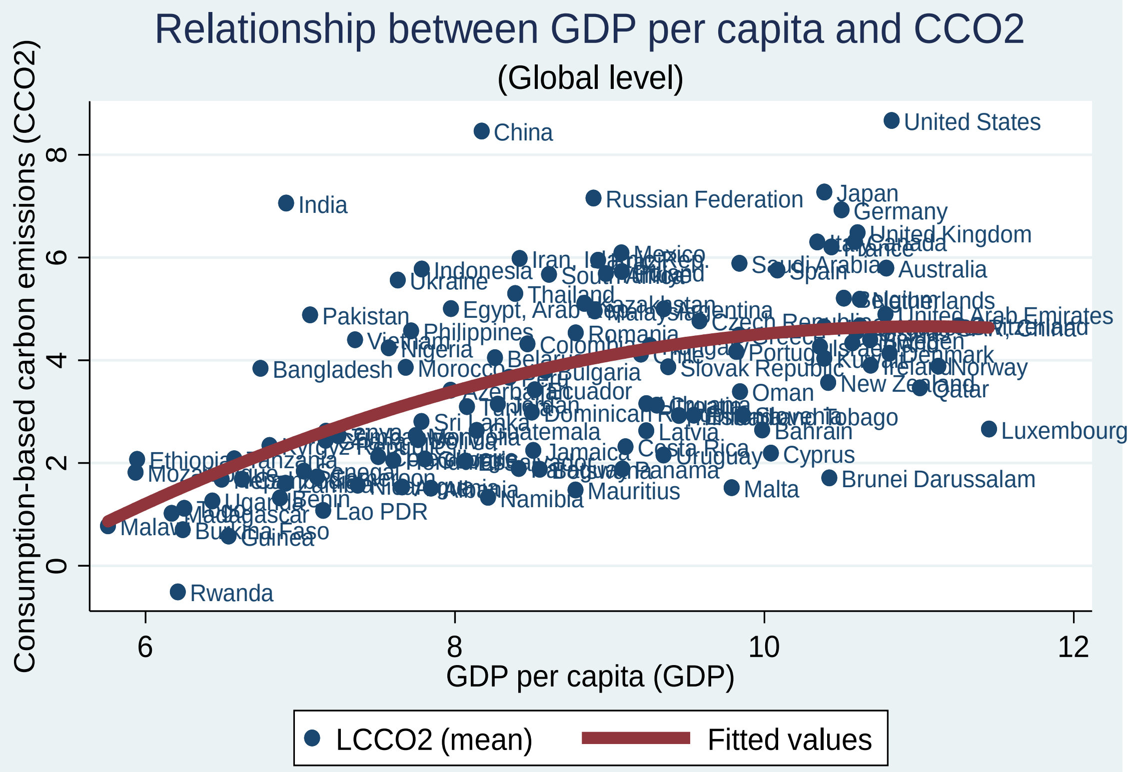


Fig 5.2: GDP and CCO2 (Global level)

Figure 5.2: GDP and CCO$_2$ mean values (Global Data)

Regarding net-importers of carbon and net-exporters of carbon emissions countries, outcomes of the results obtained from scatter plot considering average values of described variables for each cross section displayed in figure 5.3 and 5.4. Net-importers of carbon emissions are exhibiting positive link between GDP per capita and CCO$_2$. Results indicating that consumption-based carbon emissions for net-importers of carbon emissions increases with increase in GDP per capita in linear prediction. On the other side, net-exporters of carbon emissions exhibits negative link between in GDP per capita and consumption-based carbon emissions. Results indicating that consumption-based carbon emissions for net-exporters of carbon emissions decrease along with increase in GDP per capita in linear prediction.

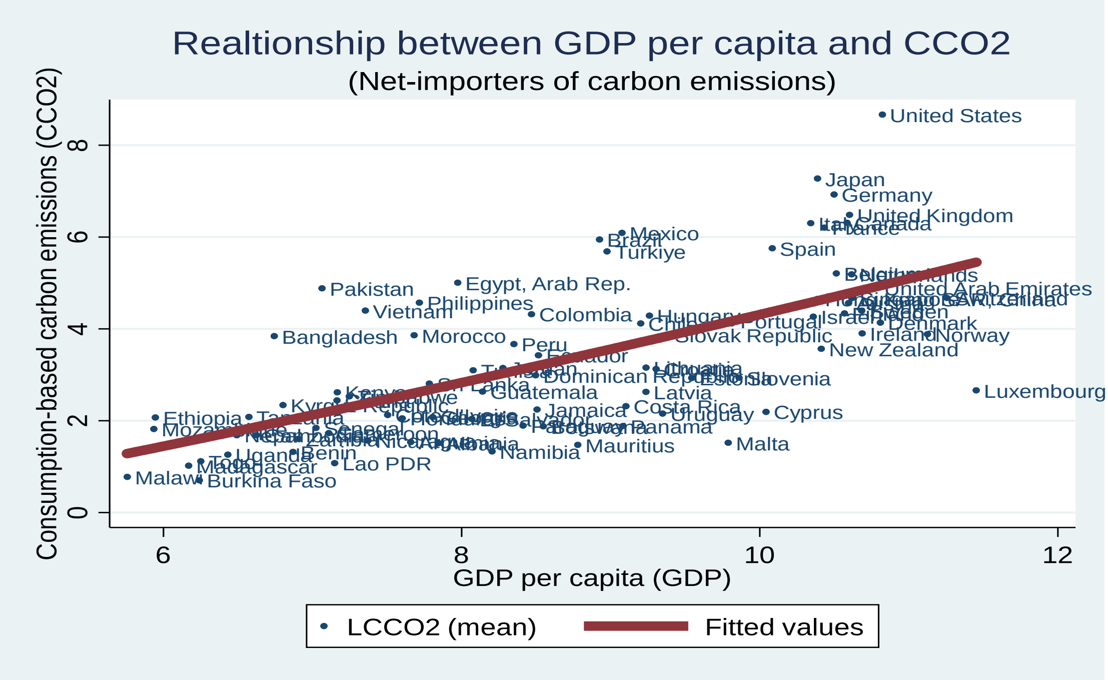


Figure 5.3: GDP and CCO$_2$ mean values (Net-importers of carbon emissions)

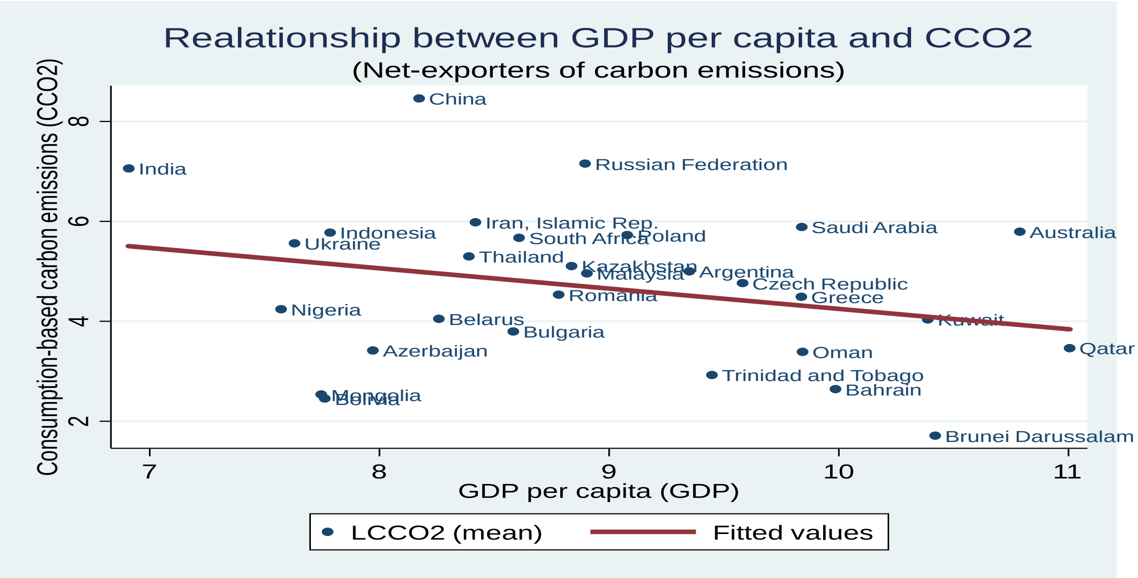


Figure 5.4: GDP and CCO$_2$ mean values (Net-exporters of carbon emissions)

5.3.2. Relationship Between Renewable Energy and Consumption-based Carbon Emissions

This sub-section of graphical analysis shows the scatter plot relating response variable CCO$_2$ to variables of interest aggregated and disaggregated renewable energy. The analysis is further divided into two parts. First part presents the relationship between described variables by considering overall data of variables for each country. While second part shows the relationship of described variables by considering average values for each cross sections.

5.3.2.1. Whole Data Analysis (Scatter Plot)

This part of graphical analysis indicates the relationship in aggregated and disaggregated renewable energy and CCO_2 by taking all data values of described variables. Scatter plot presenting in figure 5.5 shows the relationship between aggregate REC and CCO_2. The graph is clearly predicting negative association between described variables at global level.

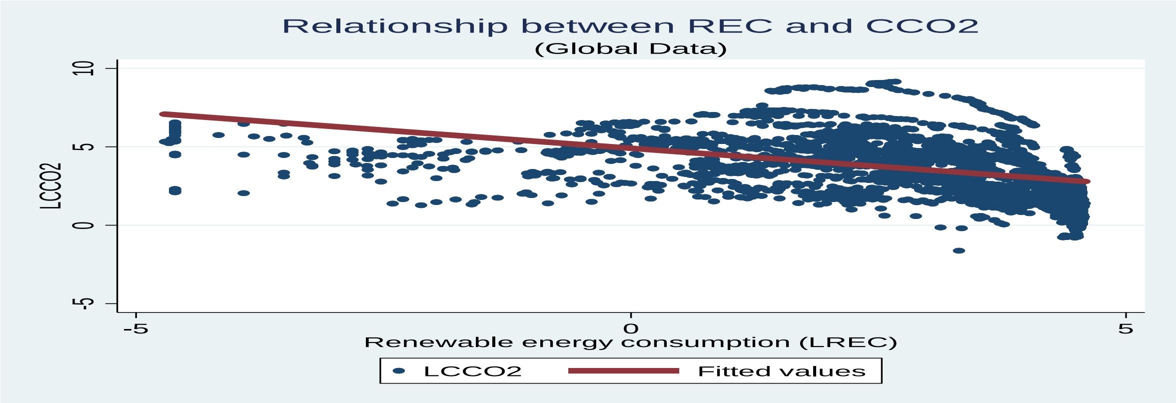


Figure 5.5: REC and CCO_2 (Global Data)

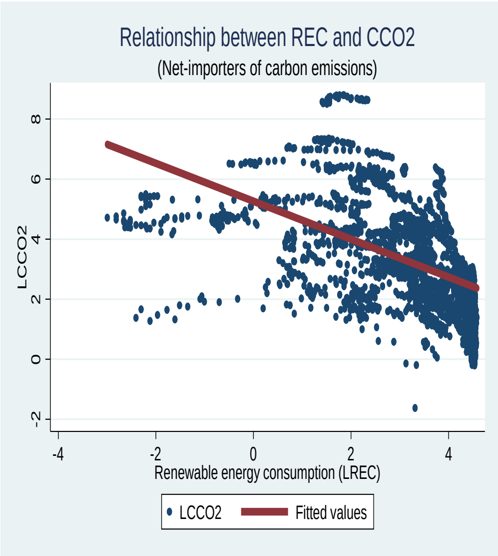


Figure 5.7: REC and CCO_2

(Net-importers of carbon emissions)

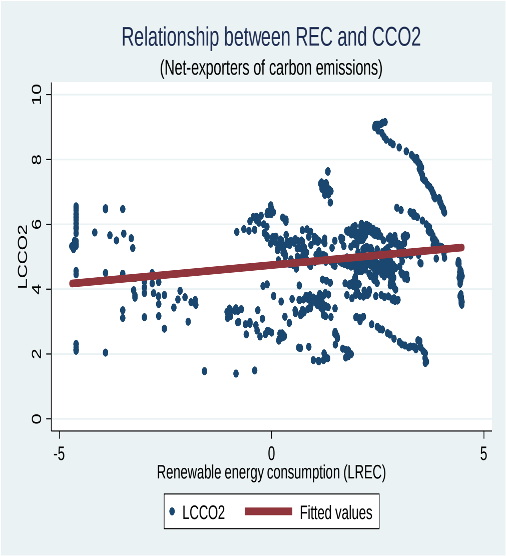


Figure 5.6: REC and CCO_2

(Net-exporters of carbon emissions)

Figures 5.6 and 5.7 represents the relationship in between aggregate renewable energy and consumption-based carbon emissions in the case of net-importers of carbon emissions and net-exporters of carbon emission countries. The line of scatter plot is indicating the REC is negatively associated with CCO_2.

Scatter plot presenting in figures 5.8 to 5.12 shows the relationship between disaggregated REC and CCO_2. The graphs are predicting positive association between consumption-based carbon emissions and electricity generated from solar energy, wind energy, biomass energy, hydropower and geothermal energy.

Scatter plots for Disaggregated Renewable energy (Global Data)

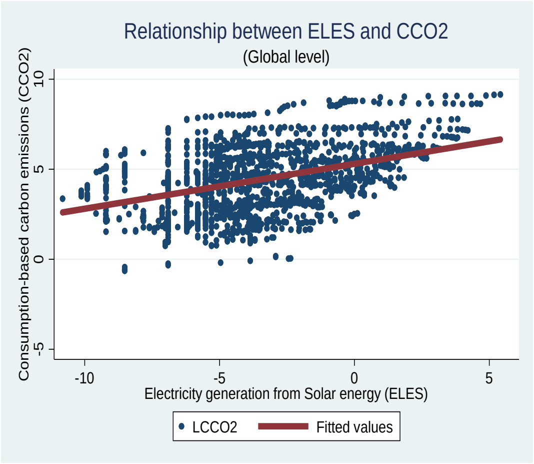


Figure 5.8: ELES & CCO_2 (Global level)

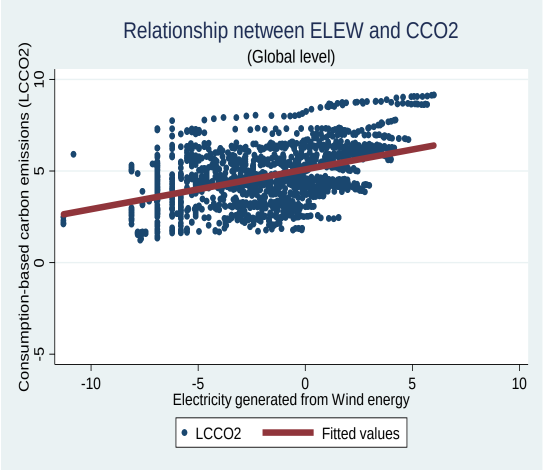


Figure 5.9: ELEW & CCO_2 (Global level)

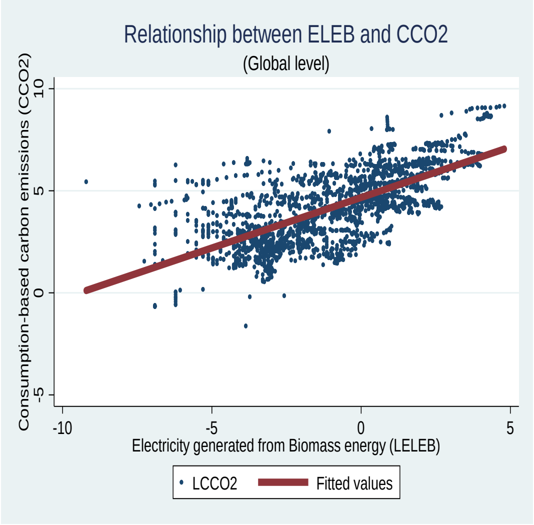


Figure 5.10: ELEB & CCO_2 (Global level)

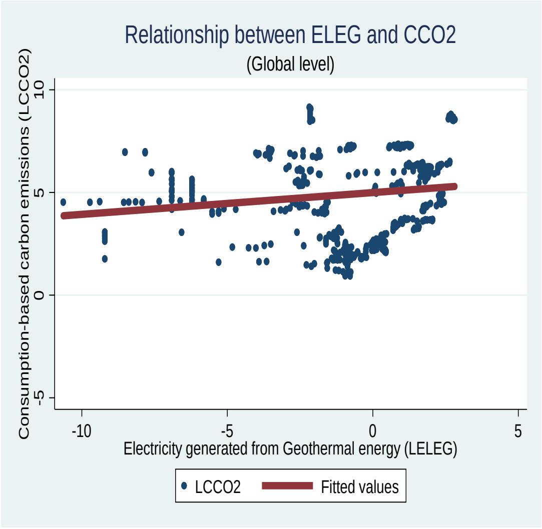


Figure 5.11: ELEG & CCO_2 (Global level)

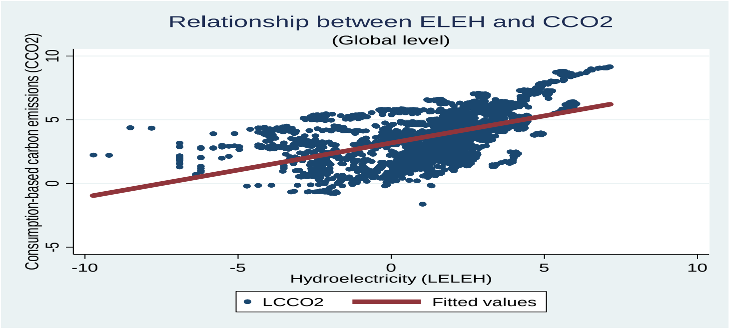


Figure 5.12: ELEH & CCO_2 (Global level)

5.3.2.2 Mean Value Analysis (Scatter Plot)

This part of graphical analysis indicates the relationship between aggregated and disaggregated renewable energy and CCO_2 on the basis of average values for each cross sections.

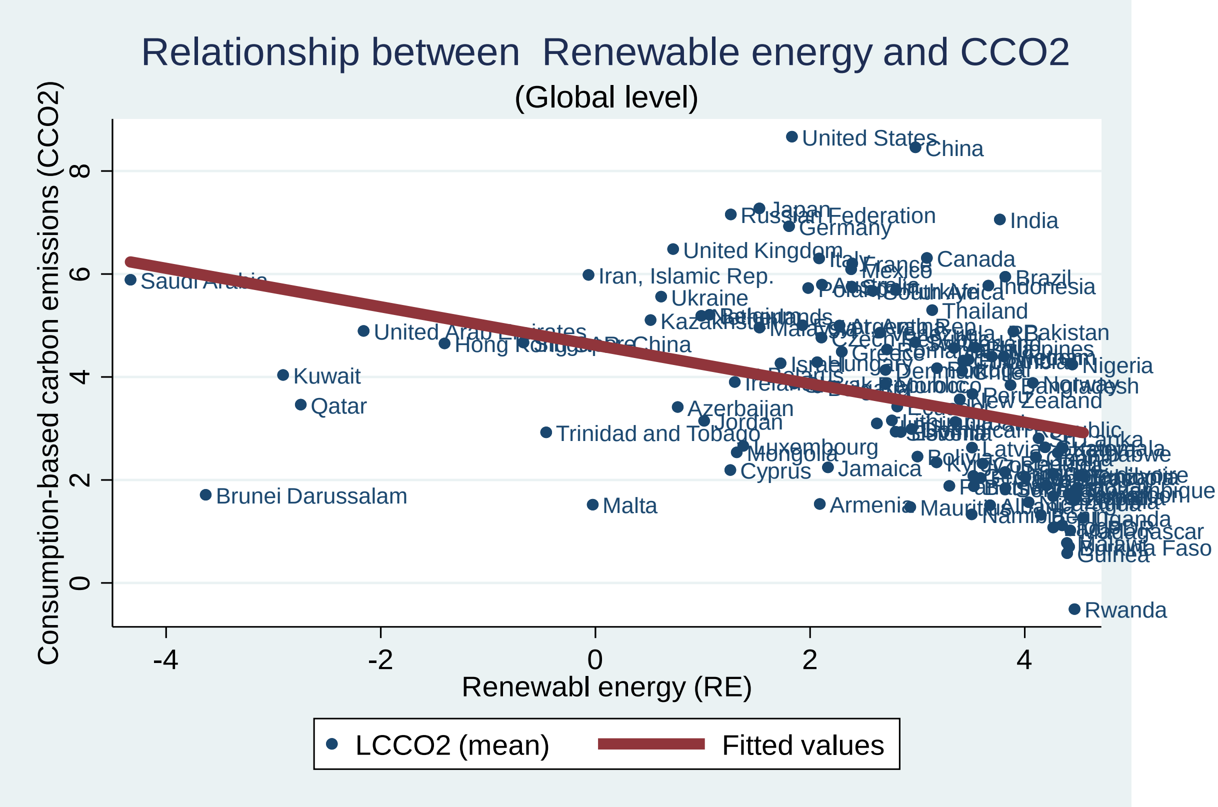


Figure 5.13: REC and CCO_2 mean values (Global Data)

Mean analysis presented in figure 5.13 is indicating negative relationship in between aggregate REC and CCO_2 at global level. Regarding net-importers and net-exporters of carbon emissions countries, results are also similar to the outcomes obtained from scatter plot considering complete data values. The relationship is displayed in figure 5.14 and 5.15.

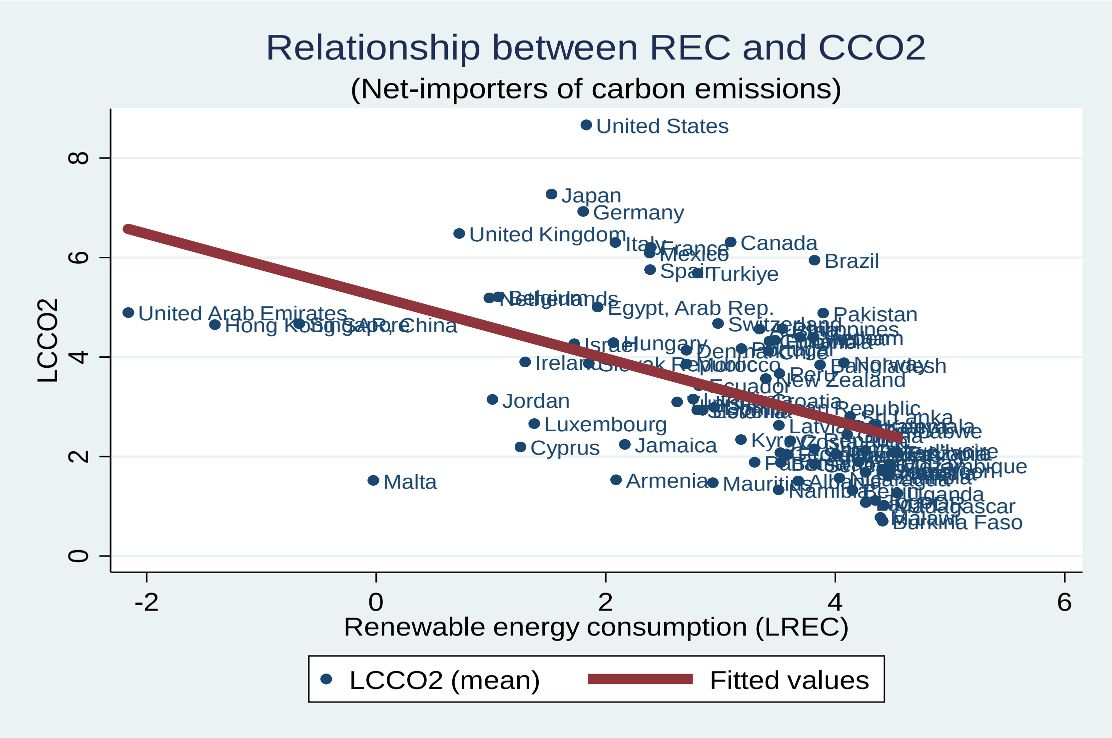


Figure 5.14: REC and CCO$_2$ mean values (Net-importers of carbon emissions)

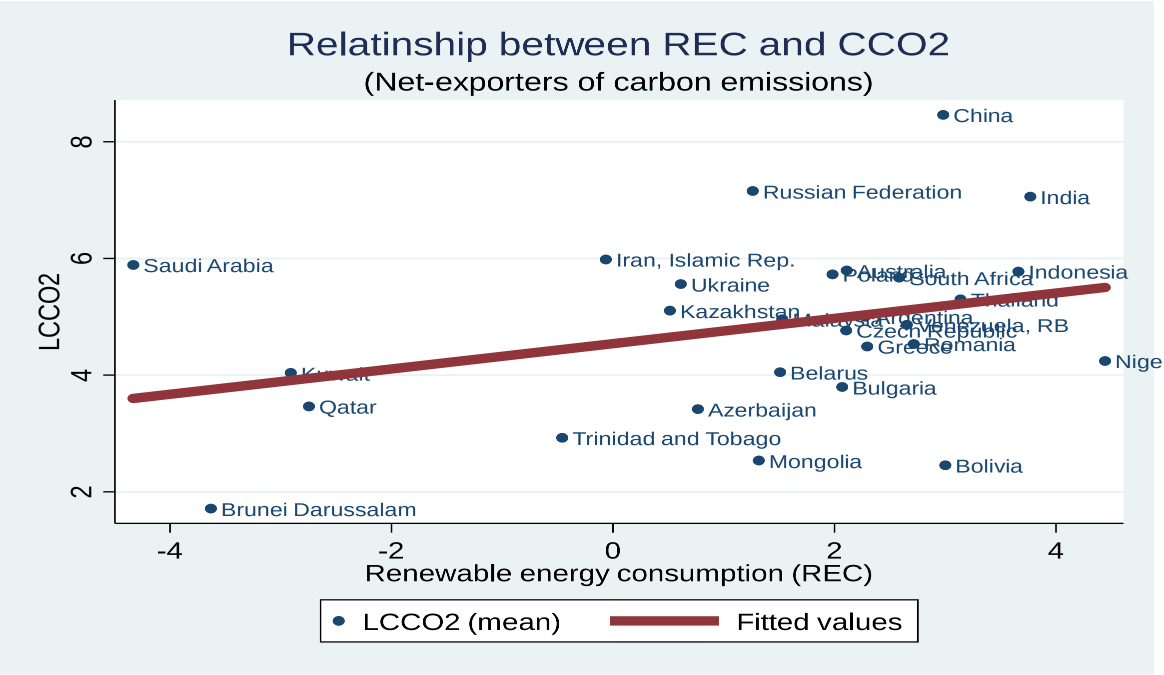


Figure 5.15: REC and CCO$_2$ mean values (Net-exporters of carbon emissions)

Scatter plots for Disaggregated Renewable energy with mean values

(Global Data)

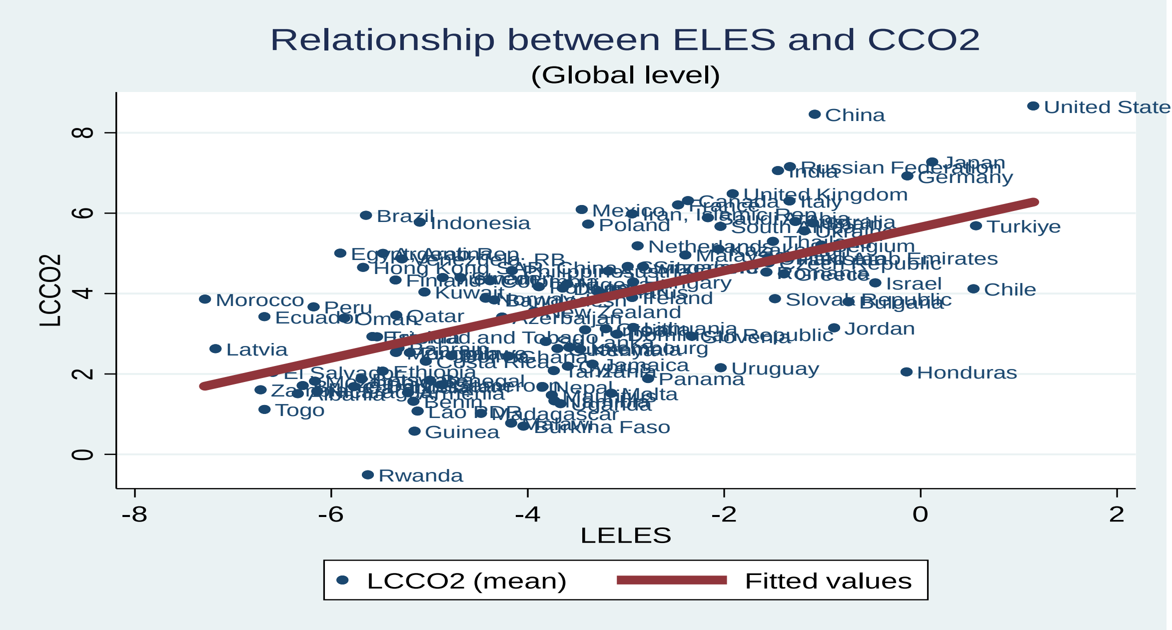


Figure 5.16: ELES and CCO$_2$ mean values (Global level)

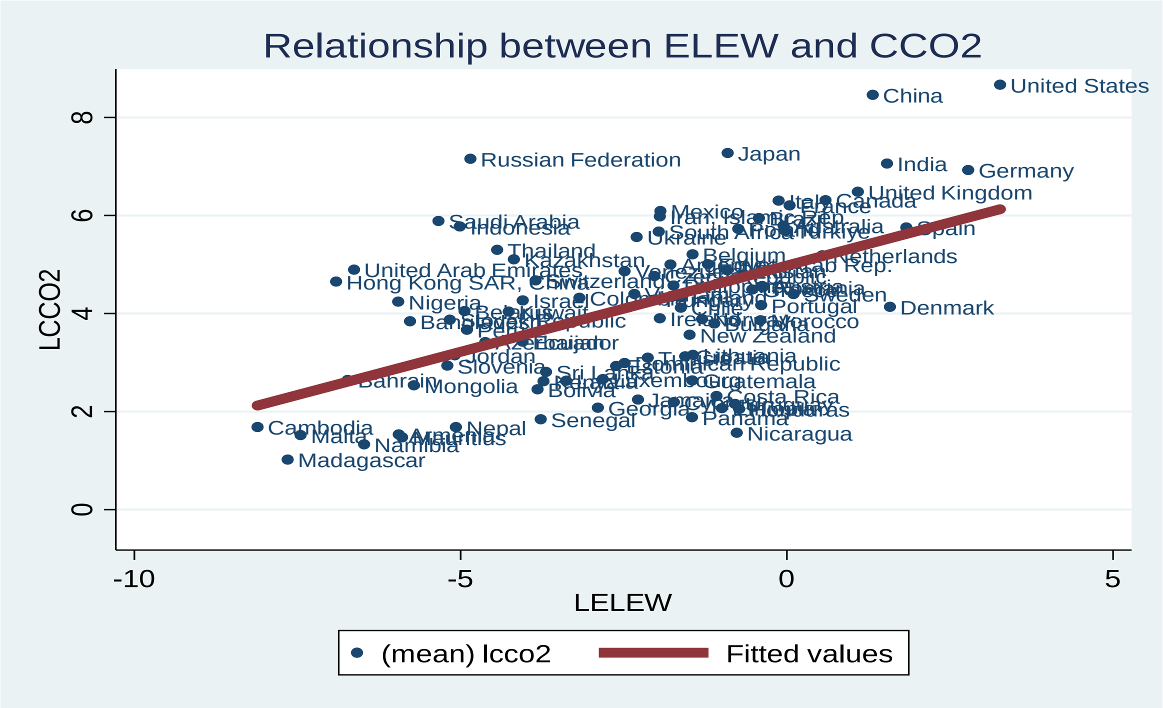


Figure 5.17: ELEW and CCO$_2$ mean values (Global level)

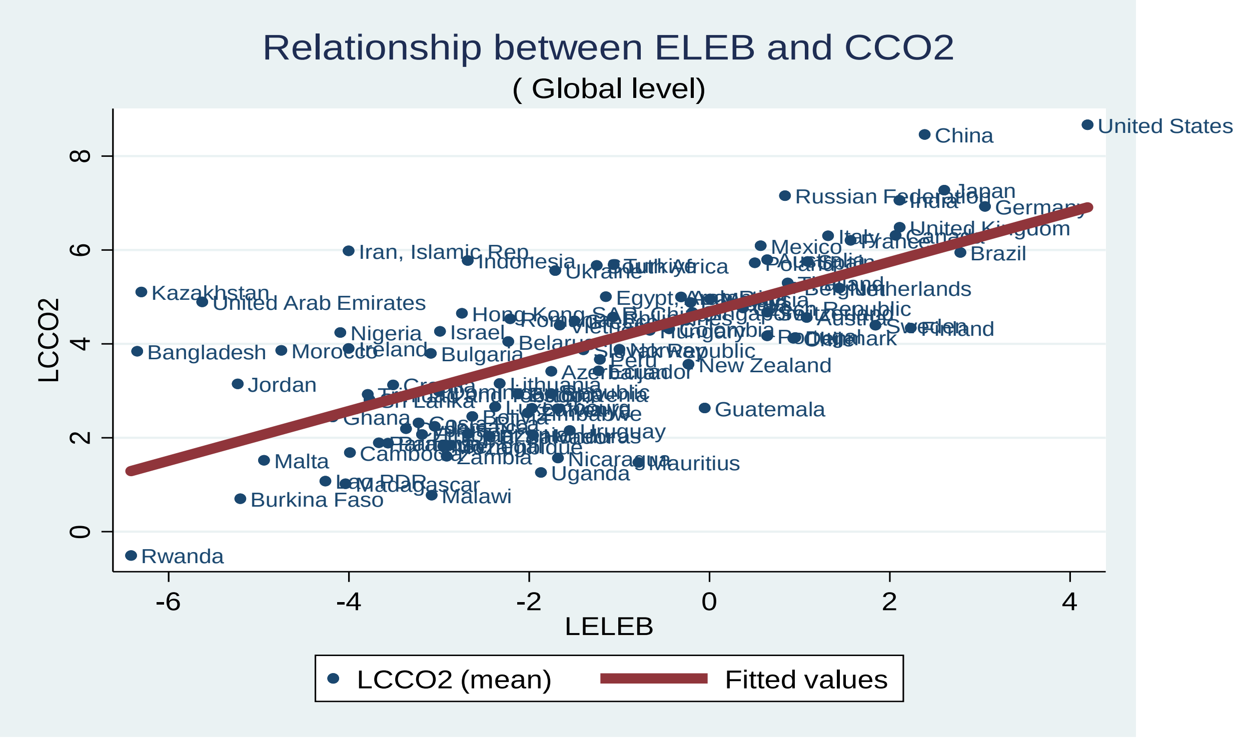


Figure 5.18: ELEB and CCO$_2$ mean values (Global level)

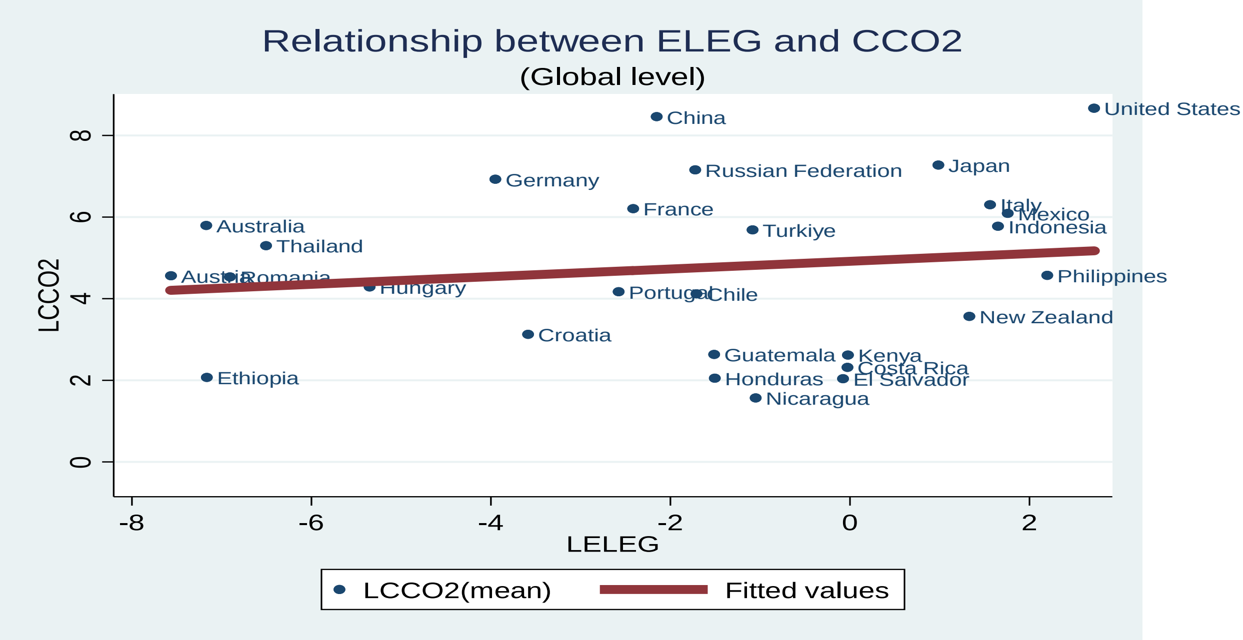


Figure 5.19: ELEG and CCO$_2$ mean values (Global level)

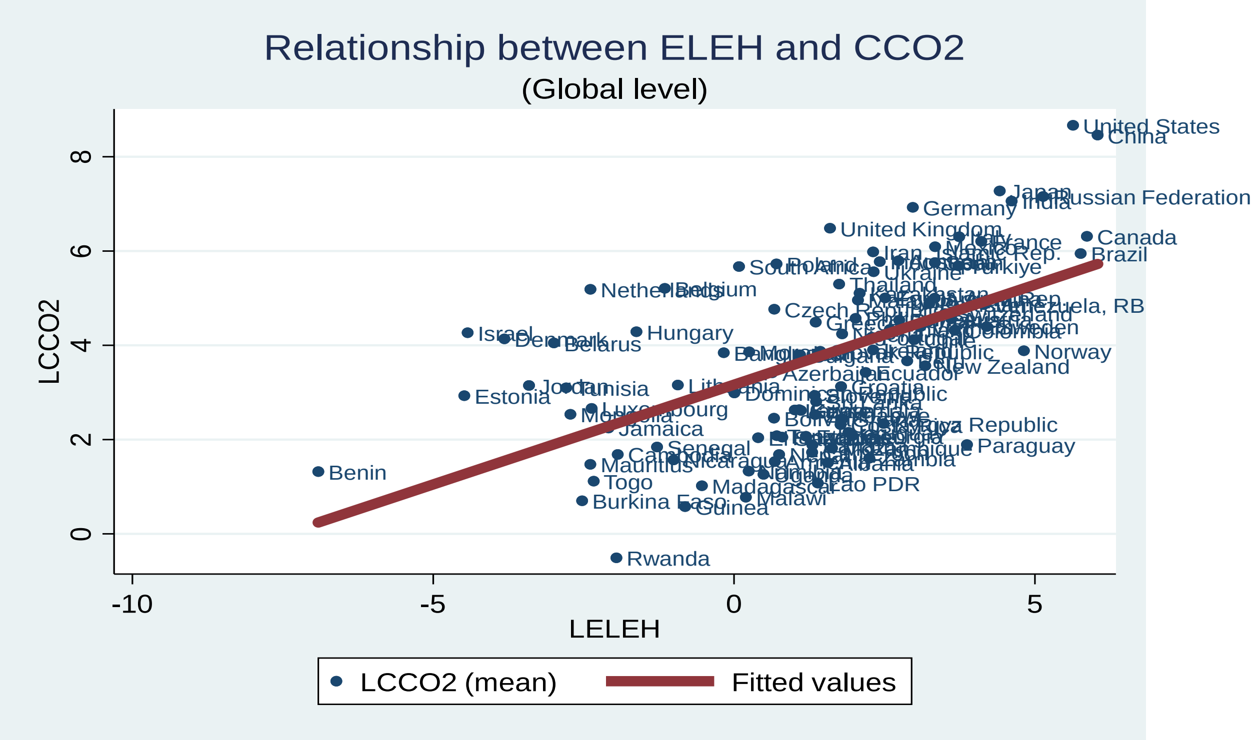


Figure 5.20: ELEH and CO$_2$ mean values (Global level)

Additionally, scatter plot relating disaggregated renewable (electricity generated from different sources of renewable energy) to CCO$_2$ on the basis of average values for each cross sections is shown in figure 5.16 to 5.20. results are also similar to the outcomes obtained from scatter plot considering complete data values.

5.4. Diagnostic Tests

This section is providing outcomes obtained from the diagnostic tests that are applied. Regression models have some specific assumptions and violation of these assumptions may lead to issues in regressions outcomes. Violation of assumptions may create problems like multicollinearity, autocorrelation, heteroskedasticity and endogeneity in the empirical model and need to be address. Thus, it is necessary to test whether data is suffering from above mentioned problems or not. Therefore, diagnostic tests are applied.

5.4.1. Heteroskedasticity

This section provides the outcomes of the test applied for heteroskedasticity.Breusch-Pagan / Cook-Weisberg test is applied to test the heteroskedasticity. Outcomes of the test revealed that all models are suffering from the problem of heteroskedasticity. P-value reported by the test is less than 0.05 which reject hypothesis (variance are constant of error terms). Table 5.3 presents the results of test.

Table 5.3: Heteroskedasticity Test

Breusch-Pagan / Cook-Weisberg						
H_0 = variance is constant						
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
Chi2(1)	177.96	76.62	16.14	29.12	142.28	4.04
P > chi2	0.0000	0.0000	0.0000	0.0000	0.0000	0.0445

5.4.2. Autocorrelation

This section provides the outcomes of the test applied for autocorrelation. To test the problem of autocorrelation Wooldridge test is applied. Outcomes of the test revealed that all models are violating the assumption of no serial correlation between error terms. Therefore, models are suffering from the problem of autocorrelation. P-value reported by the test is less than 0.05 which reject hypothesis (no first order autocorrelation). Table 5.4 presents the outcomes of autocorrelation test.

Table 5.4: Autocorrelation Test

Wooldridge test for Autocorrelation						
$H_{0:}$ no autocorrelation in the model						
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
F stat	27.636	11.023	9.066	14.873	19.243	11.476
Prob> F	0.0000	0.0013	0.0035	0.0002	0.0000	0.0026

5.4.3. Multicollinearity

This section provides the outcomes of the test applied for multicollinearity. To test the problem of multicollinearity Variance inflating factor (VIF) test is applied. Outcomes of the test revealed that models are not suffering from the problem of multicollinearity because VIF mean value for all models is less than 10. Table 5.5 presents the outcomes of multicollinearity test.

Table 5.5: Multicollinearity Test

Variance inflation factor test for multicollinearity						
	Model (1)	Model (2)	Model (3)	Model (4)	Model (5)	Model (6)
VIF(Mean)	1.82	1.75	1.68	2.03	1.85	2.42

Chapter 06

Econometric Analysis and Results Discussion

6.1. Introduction

Current chapter is providing the detailed outcomes obtained from estimation techniques for regression analysis. For the validation of EKC (non-linear relationship between GDP and CCO_2) and to explain the relationship between aggregated and disaggregated renewable energy with CCO_2 this chapter will elaborate the outcomes of econometric techniques like Pooled OLS, Random effects and Fixed effects along Driscoll and Kray estimators. Moreover, chapter will also report the outcomes obtained from SGMM that is employed to address the problem of endogeneity. Lastly, chapter will expose outcomes obtained from sensitivity analysis.

6.2. Econometric Analysis

To investigating the research question and to find out the validity of hypothesis panel data econometric techniques has utilized. As model is suffered with the problem of autocorrelation, heteroscedasticity and cross-sectional dependency. Therefore, by taking into account these problems, we applied the panel Driscoll and Kray pooled OLS, random effect and fixed effect techniques, that is robust panel data method. Which generates robust standard errors. While Driscoll and Kray pooled OLS, Random effect and Fixed effect do not address the problem of endogeneity. Therefore, SGMM is employed to address the endogeneity and for the robustness of analysis. The outcomes of all these econometric techniques for regression are described in coming sections.

6.2.1. Outcomes of Driscoll and Kray Pooled OLS

First of all, Driscoll and Kray pooled OLS technique is applied that assuming all countries in panel data set as a homogeneous.

Table 6.1: Driscoll and Kray Pooled OLS (Global Analysis)

Dependent Variable: Consumption-based carbon emissions (CCO_2)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	1.614*** (0.062)	1.941*** (0.195)	1.543*** (0.147)	2.251*** (0.092)	2.071*** (0.096)	2.136*** (0.099)
$LGDP^2$	-0.085*** (0.003)	-0.098*** (0.010)	-0.083*** (0.007)	-0.112*** (0.004)	-0.107*** (0.005)	-0.106*** (0.006)
LREC	-0.139*** (0.003)					
LELES		0.006 (0.004)				
LELEW			-0.009** (0.004)			
LELEB				-0.0334*** (0.006)		
LELEH					0.007*** (0.003)	
LELEG						-0.022*** (0.002)
LFD	0.174*** (0.029)	0.220*** (0.020)	0.136*** (0.020)	0.193*** (0.027)	0.173*** (0.027)	-0.028 (0.032)
LEINTS	0.560*** (0.013)	0.545*** (0.034)	0.636*** (0.019)	0.634*** (0.017)	0.677*** (0.022)	0.628*** (0.044)
LGFCF	0.545*** (0.0223)	0.502*** (0.0175)	0.627*** (0.0185)	0.515*** (0.0214)	0.566*** (0.0174)	0.562*** (0.042)
LURB	0.388*** (0.0209)	0.438*** (0.0167)	0.325*** (0.0189)	0.462*** (0.0247)	0.406*** (0.0183)	0.512*** (0.0455)
Constant	-23.82*** (0.2309)	-25.94*** (0.9171)	-24.68*** (0.7668)	-28.38*** (0.4974)	-27.43*** (0.4108)	-29.04*** (0.5865)
Observations	1782	1230	1197	1355	1635	334
Groups	107	104	86	89	98	25
R-square	0.95	0.95	0.95	0.95	0.95	0.99
F Stat	3309.6***	1775.3***	2215.9***	1603.2***	4035.5***	8397.5***

Standard errors in parentheses (***P < 0.01), (** P < 0.05), (* P < 0.1)

Results obtained from pooled OLS estimation is presented in table 6.1. Column labeled as A, B, C, D, E and F are representing econometric models of our study, models 1, 2, 3, 4, 5 and 6 respectively. According to outcomes obtained by Driscoll and Kray pooled OLS estimation, our findings are in line with the expectation based on EKC hypothesis. Partial marginal effect of GDP per capita on CCO_2 is calculated by β_1 + 2β GDP and GDP per capita square on CCO_2 by $2\beta_2$. Results implies that inverted U-shaped EKC is validated on all (1-6) models of regressions for global data. The results are indicating the elasticities of CCO_2 with respect to GDP per capita and GDP square is positive and negative respectively. Results are consistent with Danish et al., (2022) and Du et al., (2022).

There is twofold impact of GDP per capita on consumption-based carbon emissions. Initially, when income increases, consumer demand more goods to fulfill their consumption requirements and to maximize their utilities. While for the production of consumer goods pollution treated as input due to the utilization of environmental unfriendly resources because at lower level of income less expenditures made on environmentally friendly sources. Thus, consumer preferences lead economic activities to get more level of output. Moreover, it is harder to reduce emissions by substituting other inputs for pollution and easier to increase utility with more consumption. Therefore, scale effect dominates at initial stage. Accordingly, regression outcomes showed as economy expands consumption-based carbon emissions are more likely to increase. On the other side, when income per capita reaches at higher level consumer's preferences change. Non-homothetic preferences dominate to get clean environment thus, consumer give up additional consumption. Moreover, economies more concern about pollution and shift to service-intensive structure and invest in more advance technologies and modern energy (renewable energy) efficient production techniques. Therefore, Technique effect dominates at later stage. Accordingly, regression outcomes showed as GDP per capita increases continuously, CCO_2 is more likely to decrease.

Renewable energy is a focal point of this study. The estimation results reveal that aggregate measure of REC is negatively associated with CCO_2 at global level. Particularly, one percent rise in REC leads to 0.139 percentage points decrease in the CCO_2 at global level significantly. Results are consistent with ecological modernization theory and supports the clean development mechanism (CDM), social choice theory and environmental choice theory, which lay stress on research and development on technological innovations to attain the environmental sustainability. Utilization of renewable energy in manufacturing, electricity and transport reduce pollution intensity of production than less carbon embodied in consumer goods. Moreover, utilization of renewable energy for cooking, heating, cooling and transportation purposes reduces consumption-based carbon emissions. The beneficial effects of REC on CCO_2 outcomes are consistent with studies by Danish et al., 2022; Ding et al., 2021; Kirikkaleli and Adebayo., 2021 and khan et al.,2020.

According to pooled OLS results the coefficient of disaggregated renewable energy reveals that electricity generated from the solar, wind, biomass and geothermal energy decrease consumption-based carbon emissions. Results are consistent with Balezentis et al., 2019 for solar, wind, biomass and geothermal and Majeed et al., 2022 for biomass energy. Moreover, results also consistent with the study of Destek and Aslan (2020) for biomass and wind energy while inconsistent for solar energy. Results also reveal that increase in the utilization of hydroelectricity increase carbon emissions as 1% rise in the hydroelectricity increase CCO_2 by 0.007 percent significantly. This finding is consistent with Sahoo and Sahoo (2022) while inconsistent with Solarin et al., (2018) for hydroelectricity but consistent for biomass energy. The positive impact of hydroelectricity on CCO_2 transmitted through the construction and reservoirs of hydro plants. hydroelectricity is considered clean energy source but hydro power required dams that contribute more to global warming. The green image of hydro power dismisses, firstly, due to more emissions produce by the construction and operation of the hydro plants, because of fossils fuels combustion and steel / cement production. Secondly, although hydroelectricity does not emit direct pollution, the filled reservoirs can create carbon emissions due to wind speed and sun radiations reaching the dams surface (Bilgili et al., 2021). Moreover, global warming due to hydroelectric power plants built in tropical areas or temperature peatlands are much higher. Thirdly, plant materials in flooded area, soil and vegetation begin to rot and decompose in an anaerobic environment, results in releasing substantial amount of carbon dioxide (IPCC,2011 and National Academy of Science, 2010). Therefore, hydroelectricity impact to save environment is less as compared to damage the environment. While solar, wind, biomass and geothermal are safest sources to attain environmental sustainability.

According to pooled OLS results, financial development will bring increase in CCO_2, results are same with Shoaib et al., 2020 and khan et al., 2021. However, inconsistent with Majeed and Mazhar., 2019 and Kirikkaleli et al., 2021. Positive impact of FD on CCO_2 is transmitted through greater consumer loans that rise to more energy demand for electricity and transportation and consumption of energy consuming goods leading to increase in CCO_2 . Financial development helps in income redistribution more effectively but high living standard put pressure on environment (Duy Tung Bui., 2020). Moreover, FD leads to greater loans to more energy intensive industries, if loans provided to carbon intensive industries it creates rise in carbon footprint.

Additionally, according to results ENITS also increase the CCO_2. All columns (A-F) show positive and significant coefficient for energy intensity. For all (1-6) models, increase in one percent ENITS will bring change in CCO_2 by 0.560, 0.545, 0.636, 0.634, 0.677 and 0.628 percent respectively. Thus, results showed that higher ratio between energy supply and per unit output will create higher emissions.

Similarly, GFCF and URB also effect dependent variable positively and significantly. According to the outcomes, GFCF will bring 0.545, 0.502, 0.627, 0.515, 0.566 and 0.562 percent change in CCO_2 respectively. As it is changes CCO_2 by 0.388, 0.438, 0.325, 0.462, 0.406 and 0.512 percent respectively in all models. the value of R-square in (A-E) column shows that 1-5 models have 0.95% coefficient of determination. This indicating that model is good fit and independent variables explaining the variations in dependent variables.

6.2.2. Outcomes of Driscoll and Kray Random and Fixed Effects

Pooled OLS technique does not address the countries specific characteristics and consider all countries homogeneous. Therefore, due to this limitation random effects and fixed effects techniques are also applied for estimations. These techniques addressed unobserved country specific characteristics effects and temporal effects. Table 6.2 and 6.3 is reporting random and fixed effect outcomes.

Table 6.2: Driscoll and Kray Random effect (Global Analysis)

Dependent Variable: Consumption-based carbon emissions (CCO_2)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	2.082*** (0.170)	2.2263*** (0.289)	1.838*** (0.387)	2.141*** (0.2289)	2.457*** (0.168)	1.385*** (0.290)
LGDP^2	-0.096*** (0.010)	-0.097*** (0.014)	-0.084*** (0.022)	-0.095*** (0.013)	-0.116*** (0.010)	-0.064*** (0.0158)
LREC	-0.066*** (0.012)					
LELES		-0.015*** (0.002)				
LELEW			-0.008** (0.002)			
LELEB				-0.025*** (0.003)		
LELEH					0.006*** (0.001)	
LELEG						-0.012*** (0.003)
LFD	0.081 *** (0.016)	0.098*** (0.013)	0.0693*** (0.016)	0.041*** (0.010)	0.076*** (0.013)	-0.076*** (0.018)
LEINTS	0.577*** (0.037)	0.562*** (0.0418)	0.761*** (0.064)	0.689*** (0.048)	0.713*** (0.045)	0.931*** (0.085)
LGFCF	0.271*** (0.026)	0.254*** (0.022)	0.352*** (0.037)	0.279*** (0.028)	0.279*** (0.027)	0.491*** (0.045)
LURB	0.648*** (0.045)	0.676*** (0.039)	0.562*** (0.035)	0.618*** (0.036)	0.624*** (0.053)	0.520*** (0.068)
Constant	-24.58*** (0.502)	-26.07*** (0.895)	-24.33*** (1.383)	-25.14*** (0.852)	-26.45*** (0.482)	-24.37*** (1.060)
Observations	1782	1230	1197	1355	1635	334
Groups	107	104	86	89	98	25
R-square	0.95	0.94	0.94	0.95	0.94	0.98
Wald chi 2	1548.7***	17563***	2432.8***	7594.8***	1785.9***	8619.8***

Standard errors in parentheses (***$P < 0.01$), (** $P < 0.05$),(* $P < 0.1$)

According to the outcomes of random and fixed effects both techniques is showing that in columns (A-F) GDP per capita and its square term is showing positive and negative sign respectively that is indicating the existence of EKC hypothesis. Both random and fixed effects are revealing beneficial role of aggregated REC on CCO_2. Regarding aggregate renewable results are consistent with Danish et al., 2022; Ding et al., 2021; Kirikkaleli and Adebayo., 2021 and khan et al.,2020.

Furthermore, regarding the impact of disaggregated renewable energy random and fixed effects report same results. According to random effect technique disaggregated measures of renewable energy reveals that a 1% rise in electricity generated from solar, wind, biomass and geothermal energy decrease the CCO_2 significantly by 0.015, 0.008, 0.025 and 0.01 percent respectively. Similarly, according to fixed effect technique disaggregated measures of renewable energy reveals that a 1% rise in electricity generated from solar, wind, biomass and geothermal energy decrease the CCO_2 significantly by 0.016, 0.007, 0.024 and 0.008 percent respectively. Following the results of fixed effects solar and biomass energy effect CCO_2 with higher magnitude. However, hydroelectricity increase CCO_2 as random and fixed effects report positive sign along magnitude of 0.006 and 0.008 percent respectively. Results of disaggregated renewable energy is consistent with the studies conducted by Balezentis et al., (2019); Destek and Aslan (2020) and Sahoo and Sahoo (2012).

Table 6.3: Driscoll and Kray Fixed effect (Global Analysis)

Dependent Variable: Consumption-based carbon emissions (CCO_2)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	2.2214*** (0.341)	2.3218*** (0.248)	1.9028*** (0.420)	2.2821*** (0.400)	2.5558*** (0.309)	1.4767*** (0.391)
LGDP^2	-0.108*** (0.018)	-0.092*** (0.014)	-0.082*** (0.027)	-0.104*** (0.022)	-0.126*** (0.017)	-0.079*** (0.019)
LREC	-0.048*** (0.016)					
LELES		-0.016*** (0.002)				
LELEW			-0.007* (0.003)			
LELEB				-0.024*** (0.004)		
LELEH					0.0086** (0.003)	
LELEG						-0.008*** (0.002)
LFD	0.078*** (0.014)	0.107*** (0.010)	0.065*** (0.016)	0.044*** (0.011)	0.075*** (0.013)	-0.051** (0.021)
LEINTS	0.556*** (0.039)	0.575*** (0.037)	0.789*** (0.045)	0.644*** (0.033)	0.671*** (0.036)	0.851*** (0.101)
LGFCF	0.281*** (0.029)	0.204*** (0.019)	0.322*** (0.039)	0.278*** (0.027)	0.286*** (0.030)	0.506*** (0.050)
LURB	0.635*** (0.071)	-0.535*** (0.047)	0.505*** (0.059)	0.504*** (0.069)	0.599*** (0.069)	0.500*** (0.050)
Constant	-24.91*** (0.6691)	-24.01*** (0.7645)	-23.40*** (1.0143)	-23.77*** (0.9416)	-26.28*** (0.5536)	-23.97*** (1.4059)
Observations	1782	1230	1197	1355	1635	334
Groups	107	104	86	89	98	25
R-square (Within)	0.74	0.73	0.67	0.71	0.77	0.83
F Stat	921.45***	541.34***	1705.80***	1427.10***	1913.1***	255.81***

Standard errors in parentheses (***$P < 0.01$), (** $P < 0.05$), (* $P < 0.1$)

Additionally, both in random and fixed effects techniques results are showing positive impact of financial development, energy intensity, gross fixed capital formation and urbanization on CCO_2. Following fixed effect, in column (A-E) financial development will bring about 0.0788, 0.1073, 0.0646, 0.0428 and 0.0747 percent increase in CCO_2 while column F shows financial development will reduce CCO_2 with 0.051 percent. Similarly, energy intensity increases CCO_2 by 0.556, 0.575, 0.789, 0.644, 0.671 and 0.851 percent respectively. Moreover, in column (A-F) GFCF increase CCO_2 by 0.281, 0.204, 0.322, 0.278, 0.286 and 0.506 respectively and urbanization increases CCO_2 in column A, C, D, E and F by 0.635, 0.505, 0.504, 0.599 and 0.500 respectively while in column B that represent model 2 urbanization reduce CCO_2 by 0.535 percent.

Although pooled OLS, Random effects and Fixed effects results are applied for estimation and obtained same results but selection of the model is based on some specific tests.

6.2.3. Outcomes of Breusch & Pagan Lagrangian Multiplier (LM) Test

We have applied LM test for the selection between Pooled OLS and panel effects models (Random effects). LM, test the null of no significance differences across entities (i.e., no panel effects) against alternative hypothesis that there are significance differences in units. LM test reports the results in favor of panel (random) effects for all (1-6) models, as probability values of LM test for estimated chi square rejected null hypothesis and it is accepted that there is significance difference in cross sectional units. Table 6.4 reports the outcomes of LM test.

Table 6.4: Outcomes of Lagrangian Multiplier (LM)

Breusch & Pagan Lagrangian Multiplier (LM Test)			
H_0: No Panel effect			
Models	**Chi (2)**	**P-value> Chi (2)**	**Selected Model**
Model (1)	10773.69	0.0000	Random effect
Model (2)	6030.12	0.0000	Random effect
Model (3)	6654.03	0.0000	Random effect
Model (4)	8790.48	0.0000	Random effect
Model (5)	10894.86	0.0000	Random effect
Model (6)	1253.69	0.0000	Random effect

6.2.4. Outcomes of Hausman Test

We have applied Hausman test for the selection between Random effects and fixed effects models. Hausman test the null hypothesis that differences in coefficients of random and fixed effects models are not systematic (preferred model is random effect) against alternative hypothesis that there are systematic differences in coefficients (preferred model is fixed effects) model. Hausman test reports the results in favour of fixed effects for all (1-6) models, as probability values of the test is rejected null hypothesis and it is accepted that there is systematic difference in coefficients. Table 6.4 reports the outcomes of Hausman test.

Table 6.5: Outcomes of Hausman Test

Hausman Test			
H_0: Differences in Coefficients not systematic			
Models	**Chi (2)**	**P-value> Chi (2)**	**Selected Model**
Model (1)	40.37	0.0000	Fixed Effect
Model (2)	51.55	0.0000	Fixed Effect
Model (3)	419.95	0.0000	Fixed Effect
Model (4)	327.07	0.0000	Fixed Effect
Model (5)	34.33	0.0000	Fixed Effect
Model (6)	204.26	0.0000	Fixed Effect

According to the test regarding best technique selection for estimation purposes, it is concluded that Driscoll and Kray Fixed effect technique is more appropriate as compared to pooled OLS and random effects. While DK-fixed effects outcomes showed that solar, wind, biomass and geothermal are beneficial sources while hydro energy increase the consumption-based carbon emissions. DK-fixed effects technique addresses the issue of heterogeneity and autocorrelation but it does not address the issue of endogeneity in the model. First, we applied Granger causality test to check endogeneity in the model. Then, we applied SGMM to address the endogeneity issue.

6.2.5. Outcomes of Panel Granger Causality Test

For the purpose of causal relationship test we have applied the advance version of panel Granger Causality test proposed by Dumitrescu and Hurlin (2012) Outcomes of the results obtained by panel granger causality test presented in the table 6.6 that detect the way of causation in aggregated and disaggregated REC and consumption-based carbon emissions. The null hypothesis of test in this study is REC, ELES, ELEW, ELEB, ELEH and ELEG does not cause CCO_2. Based on probability values of Z-bar statistics, p-value showed outcomes in rejection of null hypothesis. while alternative hypothesis that REC, ELES, ELEW, ELEB, ELEH and ELEG cause CCO_2 is accepted. All sources of renewable energy significantly led to variation in CCO_2.

In addition, fluctuations in CCO_2 also cause REC. The null hypothesis of the test is CCO_2 does not cause REC, ELES, ELEW, ELEB, ELEH and ELEG also rejected. Therefore, there is evidence that two-way causality exists in aggregated and disaggregated REC and CCO_2.

Table 6.6: Outcomes of Panel Granger Causality Test

Null-Hypothesis	z-bar	p-value	Outcome	Conclusion
LREC does not granger cause $LCCO_2$	63.68	0.000	$LREC \rightarrow LCCO_2$	$LREC \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LREC	44.91	0.000	$LCCO_2 \rightarrow LREC$	
LELES does not granger cause $LCCO_2$	57.09	0.000	$LELES \rightarrow LCCO_2$	$LELES \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LELES	31.69	0.000	$LCCO_2 \rightarrow LELES$	
LELEW does not granger cause $LCCO_2$	35.85	0.000	$LELEW \rightarrow LCCO_2$	$LELEW \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LELEW	30.08	0.000	$LCCO_2 \rightarrow LELEW$	
LELEB does not granger cause $LCCO_2$	19.95	0.000	$LELEB \rightarrow LCCO_2$	$LELEB \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LELEB	38.87	0.000	$LCCO_2 \rightarrow LELEB$	
LELEH does not granger cause $LCCO_2$	44.82	0.000	$LELEH \rightarrow LCCO_2$	$LELEH \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LELEH	29.95	0.000	$LCCO_2 \rightarrow LELEH$	
LELEG does not granger cause $LCCO_2$	22.84	0.000	$LELEG \rightarrow LCCO_2$	$LELEG \leftrightarrow LCCO_2$
$LCCO_2$ does not granger cause LELEG	22.90	0.000	$LCCO_2 \rightarrow LELEG$	

Hence, bi-directional causality in the variables is one of the reasons that creates an issue of endogeneity in the models. According to the outcomes of panel Granger Causality test there are existence of endogeneity problem in models. Therefore, to addresses the issue of endogeneity, SGMM is applied to estimate the non-linear relationship in GDP and CCO_2 and role of aggregated REC and disaggregated renewable energy on CCO_2.

6.2.6. Outcomes of System Generalized Methods of Moments (SGMM)

In this study system SGMM is used to tackle the endogeneity in the models. Lagged dependent variable is also considered as a regressor in this approach. In SGMM approach two types of instrumental variables are used. Lagged values of independent variables are treated as exogenous instrumental variables. However, lagged CCO_2 is treated as endogenous instrumental variable. The results obtained by SGMM techniques are presented in table 6.7.

Column (A-F) of table 6.7 are representing the estimation of regression models (1-6) of this study. According to the outcomes obtained by SGMM, GDP per capita and CCO_2 have non-linear relationship. Initially one percent change in GDP per capita will bring 1.503 percent increase in CCO_2 but its delayed impact change consumption-based carbon emissions negatively. This outcome is revealing that initially scale effect dominates and after reaching higher level of income technique effect dominates and help out in reduction of emissions. This exists inverted U-shaped relationship between GDP per capita and consumption-based carbon emissions. Renewable energy is core variable of this study. According to the outcomes from SGMM it is indicating that aggregate measure of renewable energy consumption is negatively associated with consumption-based carbon emissions at global level. Particularly, increase of 1 percent in REC brings to 0.375 percentage points decrease in CCO_2. Following the results of SGMM renewable energy decrease emissions with higher magnitude as compared to fixed and random effects outcomes. Similarly, regarding disaggregated analysis of renewable energy solar, wind, biomass and geothermal reduces CCO_2 by 0.037, 0.026, 0.0152 and 0.032 percent respectively. However, hydroelectricity increased emissions by 0.295 percent.

Table 6.7: System GMM (Global Analysis)

Dependent Variable: Consumption-based carbon emissions (CCO_2)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
$LCCO_{2\ i,\ t-1}$	-0.253*** (0.055)	-0.268*** (0.085)	-0.178** (0.089)	-0.297*** (0.070)	-0.254*** (0.072)	-0.180
LGDP	1.503** (0.854)	2.791*** (0.869)	2.242** (1.038)	3.042*** (1.098)	2.879*** (0.508)	3.051***
$LGDP^2$	-0.084** (0.046)	-0.185*** (0.066)	-0.123** (0.056)	-0.150*** (0.054)	-0.157*** (0.026)	-0.152***
LREC	-0.375** (0.152)					
LELES		-0.037*** (0.015)				
LELEW			-0.026** (0.013)			
LELEB				-0.1529** (0.059)		
LELEH					0.295*** (0.027)	
LELEG						-0.032**
LFD	0.185** (0.073)	0.234* (0.139)	0.193** (0.094)	0.2048* (0.122)	0.278*** (0.091)	-0.109
LEINTS	0.591*** (0.220)	0.706*** (0.206)	0.832*** (0.120)	1.0045*** (0.111)	0.878*** (0.110)	0.864***
LGFCF	0.717*** (0.153)	1.653** (0.716)	0.774*** (0.142)	0.798*** (0.231)	0.827*** (0.152)	0.647***
LURB	0.453*** (0.156)	-0.257 (0.755)	0.363*** (0.122)	0.5516** (0.210)	0.427*** (0.154)	0.608***
Constant	-26.53*** (4.632)	-42.37*** (6.195)	-31.62*** (5.892)	-40.092*** (5.641)	-36.84*** (3.376)	-36.44***
Observations	1779	1123	1103	1238	1537	334
Groups	107	104	83	87	96	25
Instruments	13	12	13	14	31	15
AR (1)	0.465	0.700	0.335	0.688	0.417	0.876
AR (2)	0.286	0.146	0.272	0.099	0.113	0.168
Hansen test	0.333	0.734	0.507	0.239	0.456	0.321

Standard errors in parentheses (***P < 0.01), (** P < 0.05), (* P < 0.1)

Moreover, regarding other regressors, consumption-based carbon emissions significantly determined by its own lag value. Lag values of CCO_2 are significant in all models. Coefficients of financial development, energy intensity, gross fixed capital formation and urbanization shows positive impact on CCO_2, significantly. In SGMM the validity of instrumental variables is confirmed by Hansen test statistics. Hansen test reports the probability-values more than 0.05 for all six models, therefore, we accept the hypothesis of instruments are not overidentified. Moreover, test for autocorrelation also reports the insignificant value of AR (1) and AR (2) that indicating error terms in the all six models are uncorrelated.

6.3. Sub-Sample Analysis

This study also analyzes the econometric models for sub-sample of net-importers of carbon emissions of carbon and net-exporters of carbon emissions. For sub-sample analysis DK-fixed effect technique is applied separately on net-importers of carbon and net-exporters of carbon emissions. The outcomes of these models presented in table 6.8 and 6.9.

According to the results obtained by estimations on net-importers and net-exporters of carbon emissions EKC hypothesis existence of in both cases. As GDP and its square term revealed positive and negative sign respectively in both samples of net-importers and net-exporters of carbon emissions. Comparatively, the efforts of aggregate REC usage to reduce CCO_2 is greater for countries that are net-exporters of carbon emissions with magnitude of 0.107 percent in comparison to countries that are importers of carbon with magnitude of 0.021 percent. This finding reflects the stronger efforts by the net-exporters of carbon emissions for the substitution of non-renewable energy sources with renewable energy and green technologies.

Table 6.8: Driscoll and Kray Fixed effect (Net-importers of carbon emissions)

Dependent Variable: Consumption-based carbon emissions (CCO$_2$)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	3.072*** (0.282)	2.586*** (0.295)	2.058*** (0.528)	3.419*** (0.259)	3.428*** (0.271)	1.287*** (0.334)
LGDP^2	-0.157*** (0.016)	-0.107*** (0.018)	-0.092** (0.034)	-0.166*** (0.016)	-0.179*** (0.016)	-0.075*** (0.019)
LREC	-0.021* (0.011)					
LELES		-0.016*** (0.001)				
LELEW			-0.012*** (0.003)			
LELEB				-0.027*** (0.004)		
LELEH					0.006** (0.002)	
LELEG						-0.007** (0.002)
LFD	0.093*** (0.022)	0.104*** (0.012)	0.097*** (0.020)	0.042*** (0.012)	0.092*** (0.022)	-0.119*** (0.033)
LEINTS	0.484*** (0.040)	0.549*** (0.038)	0.738*** (0.065)	0.561*** (0.042)	0.554*** (0.039)	0.934*** (0.108)
LGFCF	0.311*** (0.035)	0.191*** (0.024)	0.306*** (0.050)	0.303*** (0.033)	0.324*** (0.037)	0.516*** (0.039)
LURB	0.464*** (0.054)	0.517*** (0.065)	0.503*** (0.079)	0.349*** (0.057)	0.431*** (0.050)	0.675*** (0.075)
Constant	-26.53*** (0.580)	-24.51*** (0.8893)	-23.77*** (1.438)	-26.87*** (0.822)	-27.82*** (0.602)	-25.47*** (1.373)
Observations	1388	949	910	1039	1268	282
Groups	82	77	64	68	75	20
R-square (Within)	0.76	0.72	0.63	0.71	0.79	0.85
F Stat	913.5***	395.8***	1714.7***	765.6***	1149.4***	298.9***

Standard errors in parentheses (***P < 0.01), (**P< 0.05), (*P< 0.10)

Table 6.9: Driscoll and Kray Fixed effect (Net-exporters of carbon emissions)

Dependent Variable: Consumption-based carbon emissions (CCO$_2$)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	0.750*** (0.17)	0.996*** (0.232)	1.208*** (0.273)	1.229*** (0.107)	1.045*** (0.161)	4.338*** (1.077)
LGDP^2	-0.010 (0.009)	-0.021 (0.015)	-0.038** (0.015)	-0.033*** (0.009)	-0.025** (0.008)	-0.255*** (0.049)
LREC	-0.107*** (0.032)					
LELES		-0.008*** (0.003)				
LELEW			0.001 (0.006)			
LELEB				-0.021** (0.008)		
LELEH					0.045* (0.024)	
LELEG						-0.024 (0.017)
LFD	0.004 (0.024)	0.162*** (0.047)	-0.016 (0.024)	-0.0205 (0.0237)	-0.0312 (0.0224)	0.113** (0.043)
LEINTS	0.809*** (0.097)	0.684*** (0.157)	0.908*** (0.105)	0.878*** (0.087)	0.951*** (0.088)	0.397*** (0.131)
LGFCF	0.255*** (0.045)	0.316*** (0.068)	0.347*** (0.059)	0.273*** (0.062)	0.295*** (0.052)	0.447*** (0.137)
LURB	0.816*** (0.077)	0.467*** (0.138)	0.622*** (0.083)	0.736*** (0.075)	0.767*** (0.065)	0.584*** (0.124)
Constant	-21.95*** (1.543)	-19.59*** (2.640)	-23.08*** (1.274)	-23.78*** (1.098)	-23.94*** (1.162)	-35.18*** (3.318)
Observations	360	257	287	296	333	52
Groups	23	25	22	20	21	5
R-square (Within)	84	0.81	0.76	0.85	0.82	0.92
F Stat	649.58***	125.20***	193.35***	750.76***	1134***	314.4***

Standard errors in parentheses (***P < 0.01), (** P < 0.05), (* P < 0.1)

Accordingly, outcomes obtained from disaggregated analysis suggested that solar, biomass and geothermal reduces CCO$_2$ along magnitude of 0.008, 0.021 and 0.024 percent respectively and improve environmental quality while hydroelectricity and wind energy degrade environmental quality with magnitude of 0.001 and 0.045 respectively for net-exporters of carbon emissions. The impact of wind and geothermal energy, however, turns out to be insignificant. For net-importers of carbon emissions, results showed that solar, wind, biomass and geothermal reduces CCO_2 by coefficients of 0.016, 0.012, 0.027 and 0.007 percent respectively while hydroelectricity increases CCO_2 by 0.006 percent significantly.

Financial development, energy intensity, gross fixed capital formation and URB increase CCO_2 for net-importers of carbon emissions significantly for all models of the study. For net-exporters of carbon emissions energy intensity, gross fixed capital formation and urbanization effect consumption-based carbon emissions significantly in all models while financial development turns negative and insignificant for wind, biomass and hydroelectricity models but positive and significant for solar and geothermal.

6.2.8. Sensitivity Analysis

Lastly, we have conducted the estimation for the sensitivity analysis. This estimation analysis is conducted to investigate the robustness of outcomes obtained by previous estimations. In this purpose, we have included additional variable in already formatted models. variable of inflation is added as a determinant of CCO_2 in the models to check the robustness of the present study analysis. For, sensitivity analysis, DK-fixed effects technique is used that is reported in table 6.10.

Table 6.10: Sensitivity Analysis (DK- Fixed Effects)

Dependent Variable: Consumption-based carbon emissions (CCO$_2$)						
	(A)	**(B)**	**(C)**	**(D)**	**(E)**	**(F)**
LGDP	2.277*** (0.416)	2.237*** (0.205)	2.069*** (0.436)	2.075*** (0.528)	2.427*** (0.419)	1.701*** (0.4170
LGDP^2	-0.108*** (0.023)	-0.087*** (0.017)	-0.091*** (0.028)	-0.089** (0.031)	-0.116*** (0.023)	-0.088*** (0.020)
LREC	-0.033** (0.015)					
INFLATION	0.021*** (0.005)	0.014** (0.005)	0.016*** (0.004)	0.013** (0.005)	0.024*** (0.005)	0.024*** (0.004)
LELES		-0.014*** ((0.002)				
LELEW			-0.005* (0.002)			
LELEB				-0.018*** (0.003)		
LELEH					0.009* (0.004)	
LELEG						-0.006** (0.002)
LFD	0.078*** (0.015)	0.101*** (0.010)	0.066*** (0.016)	0.044*** (0.010)	0.077*** (0.0150	-0.035* (0.0180
LEINTS	0.586*** (0.034)	0.589*** (0.039)	0.749*** (0.055)	0.699*** (0.045)	0.688*** (0.029)	0.866*** (0.114)
LGFCF	0.248*** (0.027)	0.192*** (0.022)	0.284*** (0.045)	0.241*** (0.027)	0.257*** (0.026)	0.477*** (0.054)
LURB	0.684*** (0.070)	0.588*** 0.059)	0.522*** (0.070)	0.552*** (0.075)	0.657*** (0.068)	0.531*** (0.062)
Constant	-25.49*** (1.023)	-24.15*** (0.833)	-23.48*** (1.114)	-23.08*** (1.393)	-26.28*** (0.904)	-25.16*** 1.532)
Observations	1782	1230	1197	1355	1635	334
Groups	107	104	86	89	98	25
R-square (Within)	0.74	0.72	0.65	0.70	0.78	0.85
F Stat	581.9***	651***	237.4***	828.6***	2222***	544.8

Standard errors in parentheses (***P < 0.01), (** P < 0.05), (*P < 0.10)

According to the outcomes obtained by conducting sensitivity analysis it is concluded that outcomes of the baseline models are robust and consistent. Inclusion of new variable do not disturb the consistency of the baseline models outcomes and variables behaved similar manners. Coefficients of all variables are showing same sign and significancy in the presence of additional independent variable. Thus, the analysis conducted for global data for determination of EKC hypothesis and relationship between aggregated and disaggregated renewable energy with consumption-based carbon emissions are robust and consistent.

CHAPTER 07

CONCLUSION AND POLICY RECOMMENDATIONS

7.1. Introduction

Globally carbon emissions required collective measures to mitigate environmental degradation. Policy measures based on Production-based carbon emissions could not reduce emissions globally, in fact its source carbon leakage, in this context Consumption-based accounting imperative. Even though renewable energy impacts on carbon emissions have been an area of interest recently, it has not been investigated for the potential role of renewable sources separately for CCO_2. Recently, transition towards green energy imperative for sustainable development, for sustainability required investment to substitutional sources of non-renewable energy that is renewable energy. Which source of renewable energy has more potential to mitigate environmental hazards and should be more invested, in this context require disaggregated analysis of renewable energy.

7.2. Conclusion of the study

This study reinvestigated the Environmental Kuznets curve by taking consumption-based carbon emissions (i.e., adjusted for trade) as an environmental indicator and incorporated renewable energy, financial development, energy intensity, urbanization and gross fixed capital formation in the EKC model.

Present study explored the effect of REC not only aggregate level but also investigated the influence of disaggregated renewable energy on CCO_2 by segregating renewable energy according to electricity generation into solar, wind, biomass, geothermal and hydroelectricity. The relationship is analyzed at the global level, and for the net-importers and net-exporters of emission countries over the period 1990-2021.

Empirical techniques strategy is proceeded in following steps: Firstly, Heteroskedasticity and Autocorrelation in the dataset is tested using Breusch-Pagan / Cook-Weisberg test for Heteroskedasticity and Autocorrelation is tested by Wooldridge. Results showed that model is suffering from the problems of Heteroskedasticity and Autocorrelation. Secondly, For the purpose of empirical analysis, the traditional econometric techniques for panel data models including pooled OLS, Random and Fixed effects models along Driscoll-Kray regression.

Outcomes of our study validated the non-linear relationship in economic growth and CCO_2. The study depicted that EKC existed for global analysis. Moreover, outcomes are showing inverted U-shaped curve in our study. EKC is also validated for the sub-sample analysis of net-importers of carbon emissions and net-exporters of carbon emissions. Findings about aggregate renewable energy revealed that renewable sources are affecting CCO_2 significantly and helps to reduce environmental degradation at global level. In case of sub-sample analysis renewable energy also gives consistent results to reduce emissions. Comparatively, REC effects are greater for the countries that are net exporters of carbon emissions in comparison to net importers of carbon emissions. This finding reflects that net-exporters of carbon has taken stronger efforts for installation of renewable energy and green technologies, for the substitution of fossils fuels sources.

The disaggregation of renewable energy sources into solar, wind, biomass, geothermal and hydroelectricity suggests that solar, wind, biomass and geothermal enhance environmental quality while hydroelectricity deteriorate environmental quality by significantly effects on consumption-based carbon emissions for global analysis. Since, hydroelectricity requires a large area for dams' construction that emits carbon emissions. Moreover, filled reservoirs create carbon emissions due to wind speed and sun radiations reaching dam's surface. Further, substantial amount of carbon dioxide releasing as a result of decomposition of plant materials in flooded area. Therefore, hydroelectricity impact to save environment is less as compared to damage environment.

For net-exporters of emissions results showed that solar, biomass and geothermal reduce Consumption-based carbon emissions and improve environmental quality while hydroelectricity and wind degrade environmental quality. The impacts of wind and geothermal energy, however, turns out to be the insignificant. For net-importers of emissions results showed that solar, wind, biomass, geothermal and hydroelectricity reduce consumption-based carbon emissions. The impact of hydroelectricity, however, turns out to be insignificant for net-importers of emissions.

Thirdly, to check causality between variables, applied Granger causality test. Results revealed two-way causality between dependent variable and focus variables. Therefore, System GMM is applied to address endogeneity, which provides robust estimates. Results support main findings of the study. The main findings of the study also confirmed through sensitivity analysis. Results are consistent along previous literature.

7.3. Policy Recommendations

Empirical findings suggest following policy recommendations that governments should impose at commercial and domestic levels.

- Study suggests that to mitigate hazardous of CCO_2, domestic and commercial energy consumption in each country should be addressed, especially, in more energy intensive sector that rise more carbon emissions.

- Study suggests that CCO_2 provide clearer picture of global carbon-emissions that helps to make policies regarding mitigating environmental degradation. Categorization of countries into net-importers and net-exporters of emissions will guide policy makers to pay more attention regarding their traded goods and impose taxes on those goods which embodied high carbon emissions.

- Study suggests that electricity generation from renewable energy reduces consumption-based carbon emissions not only net-exporters of emissions but also net-importers of emissions countries. Therefore, they should minimize their dependency on traditional energy sources. Moreover, net importer of emission countries should focus on their consumption pattern towards sustainable energy consumption to avoid carbon leakage phenomena.

- It has been demonstrated that renewable energy (solar, wind, biomass and geothermal) improves while hydroelectricity worsens environmental quality. Governments should prioritize the installation of solar panels, wind turbines and electricity generation from biomass and geothermal energy by allocating financial resources. Government should encourage local and foreign investment in production of electricity from solar, wind, biomass and geothermal energy. This would reduce countries dependency on energy import and also address the issues of energy security.

- Governments should organize public awareness that encourages the urban citizens in favor of renewable energy installation. Due to increase in urban population and pattern of energy consumption boosted by household energy consumption and transportation sector put on environmental hazards. Government should emphasize on increasing electric appliances that are more energy efficient resident and renewable energy for household sector at affordable prices. Governments should provide soft loans and other incentives.

- Governments should place lower tax rates and subsidizing businesses that use sustainable energy in their production.

7.4. Study Limitations

This research has few limitations that can cover in future research studies:

- First, this study used unbalanced panel data because variables in the model being estimated had missing values, especially dependent variable data is available for approximately 117 countries. When complete data available in future, the estimation can be more effectively.
- The study has used only CCO_2 proxy to measure the quality of environment while comparative analysis between CCO_2 and PCO_2 is not estimated.
- This study has used first generation approach for estimations due to data limitations while recently, created second generation econometric approaches can be used in the future when data is available in more sufficient quantity.
- We estimated the effect of disaggregated renewable energy on CCO_2 emissions globally and in net-importers and net-exporters of emission countries. This study divided countries into sub-sample of net-importers and net-exporters of emissions but

analysis is not conducted for separate country. Moreover, comparison between net-importers and net-exporters is not clear in the study because different sources of renewable energy have different number of groups.

7.5. Future Research Directions

- In future research can be extended for larger panel for global analysis and for specific country analysis when complete data available in the future. Moreover, this research can be extended for comparative analysis of regional and different group of countries.

- In future trade adjusted emission can be measured by making comparison in emission intensity of production and emission intensity of consumption processes.

- Future research can extend by considering institutional framework and imports and exports as an important determinant of CCO_2 as it is adjusted for trade. Moreover, countries consumption pattern effects Consumption-based carbon emissions. Therefore, effect of different consumable goods can be determinant of CCO_2.

- Study has used proxies of electricity production from different sources of renewable energy, future studies can also estimate impact of electricity consumption from different sources of renewable energy or other proxies of renewable energy.

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Appendix

Table 1: List of Countries (Net-importers of Carbon Emissions)

Country	CCO_2/ PCO2	CCO2 – PCO2	Outcomes
Albania	1.2594	0.9858	Importer of emissions
Armenia	1.062	0.2859	Importer of emissions
Austria	1.4015	27.4866	Importer of emissions
Bangladesh	1.2838	12.052	Importer of emissions
Belgium	1.5743	67.0718	Importer of emissions
Benin	1.5226	1.6513	Importer of emissions
Botswana	1.9334	4.0146	Importer of emissions
Brazil	1.0489	18.5108	Importer of emissions
Burkina Faso	1.3994	0.6878	Importer of emissions
Cambodia	1.6819	2.9978	Importer of emissions
Cameroon	1.3099	1.4694	Importer of emissions
Canada	1.0142	8.2998	Importer of emissions
Chile	1.0538	3.3171	Importer of emissions
Colombia	1.114	7.8732	Importer of emissions
Costa Rica	1.682	4.3323	Importer of emissions
Cote d'ivoire	1.257	1.8461	Importer of emissions
Croatia	1.170	3.3771	Importer of emissions
Cyprus	1.299	2.1043	Importer of emissions
Denmark	1.216	11.204	Importer of emissions
Dominican Republic	1.109	2.0456	Importer of emissions
Ecuador	1.131	3.9392	Importer of emissions
Egypt	1.001	0.2402	Importer of emissions
El Salvador	1.383	2.1809	Importer of emissions
Estonia	1.004	0.0786	Importer of emissions
Ethiopia	1.447	2.9541	Importer of emissions
Finland	1.348	19.9178	Importer of emissions
France	1.305	116.3667	Importer of emissions
Georgia	1.141	1.0467	Importer of emissions
Germany	1.172	150.5495	Importer of emissions
Ghana	1.421	3.8142	Importer of emissions
Guatemala	1.358	3.9271	Importer of emissions
Honduras	1.294	1.9338	Importer of emissions
Hong Kong	2.708	66.7017	Importer of emissions
Hungary	1.291	16.534	Importer of emissions
Ireland	1.246	9.9602	Importer of emissions
Israel	1.248	14.3605	Importer of emissions
Italy	1.266	115.6014	Importer of emissions
Jamaica	1.065	0.5915	Importer of emissions
Japan	1.174	214.4812	Importer of emissions
Jordan	1.310	5.7568	Importer of emissions
Kenya	1.452	4.7212	Importer of emissions

Kyrgyz republic	1.435	3.4712	Importer of emissions
Lao PDR	1.172	0.7851	Importer of emissions
Latvia	1.552	4.9831	Importer of emissions
Lithuania	1.539	8.5425	Importer of emissions
Luxembourg	1.517	5.3601	Importer of emissions
Madagascar	1.482	0.9991	Importer of emissions
Malawi	2.208	1.2251	Importer of emissions
Malta	1.920	2.2439	Importer of emissions
Mauritius	1.445	1.3836	Importer of emissions
Mexico	1.057	24.5405	Importer of emissions
Morocco	1.139	6.0355	Importer of emissions
Mozambique	2.725	4.9853	Importer of emissions
Namibia	1.912	2.2701	Importer of emissions
Nepal	1.593	2.7053	Importer of emissions
Netherlands	1.065	11.1792	Importer of emissions
New Zealand	1.070	2.3468	Importer of emissions
Nicaragua	1.252	1.0089	Importer of emissions
Norway	1.153	6.4751	Importer of emissions
Pakistan	1.053	7.1761	Importer of emissions
Panama	1.459	3.3077	Importer of emissions
Paraguay	1.530	2.4363	Importer of emissions
Peru	1.142	5.1913	Importer of emissions
Philippines	1.256	20.4941	Importer of emissions
Portugal	1.166	9.3463	Importer of emissions
Senegal	1.178	1.0355	Importer of emissions
Singapore	2.191	58.8153	Importer of emissions
Slovak republic	1.163	6.7977	Importer of emissions
Slovenia	1.220	3.4172	Importer of emissions
Spain	1.109	31.6957	Importer of emissions
Sri Lanka	1.548	6.6012	Importer of emissions
Sweden	1.553	29.0457	Importer of emissions
Switzer land	2.517	65.1152	Importer of emissions
Tanzania	1.759	4.2988	Importer of emissions
Togo	2.281	2.1112	Importer of emissions
Tunisia	1.017	0.3894	Importer of emissions
Turkey	1.120	32.8810	Importer of emissions
Uganda	1.673	1.6676	Importer of emissions
UAE	1.187	23.6044	Importer of emissions
United Kingdom	1.254	133.4287	Importer of emissions
USA	1.038	215.6363	Importer of emissions
Uruguay	1.510	3.0393	Importer of emissions
Vietnam	1.065	6.5603	Importer of emissions
Zambia	1.710	2.2748	Importer of emissions
Zimbabwe	1.065	0.7906	Importer of emissions

Table 2: List of Countries (Net-exporters of Carbon Emissions)

Country	CCO_2/ PCO2	CCO2 – PCO2	Outcomes
Argentina	0.965	-5.4476	Exporter of emissions
Australia	0.910	-32.8543	Exporter of emissions
Azerbaijan	0.868	-4.7268	Exporter of emissions
Bahrain	0.645	-7.8539	Exporter of emissions
Belarus	0.916	-5.3871	Exporter of emissions
Bolivia	0.945	-0.7302	Exporter of emissions
Brunei Darussalam	0.917	-0.5325	Exporter of emissions
Bulgaria	0.869	-6.7202	Exporter of emissions
China	0.866	-821.143	Exporter of emissions
Czech Republic	0.955	-5.4360	Exporter of emissions
Greece	0.983	-1.5188	Exporter of emissions
India	0.929	-97.4996	Exporter of emissions
Indonesia	0.969	-11.2777	Exporter of emissions
Iran	0.934	-29.8555	Exporter of emissions
Kazakhstan	0.771	-50.7759	Exporter of emissions
Kuwait	0.881	-8.0909	Exporter of emissions
Malaysia	0.926	-12.3384	Exporter of emissions
Mongolia	0.924	-1.3767	Exporter of emissions
Nigeria	0.911	-7.433	Exporter of emissions
Oman	0.983	-0.5982	Exporter of emissions
Poland	0.913	-29.1851	Exporter of emissions
Qatar	0.627	-21.1921	Exporter of emissions
Romania	0.947	-5.1993	Exporter of emissions
Russian federation	0.784	-357.928	Exporter of emissions
Saudi Arabia	0.960	-16.3223	Exporter of emissions
South Africa	0.709	-120.108	Exporter of emissions
Thailand	0.998	-0.2085	Exporter of emissions
Trinidad and Tobago	0.601	-13.0429	Exporter of emissions
Ukraine	0.785	-73.3524	Exporter of emissions
Venezuela, RB	0.856	-22.2998	Exporter of emissions

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