



T.C.

ANKARA YILDIRIM BEYAZIT UNIVERSITY

FACULTY OF SOCIAL SCIENCES

THE THREE EMPIRICAL ESSAYS ON ENVIRONMENTAL ECONOMICS

PHD DISSERTATION

Zeeshan MALIK

DEPARTMENT OF SOCIAL POLICY

ANKARA, 2022

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APPROVAL PAGE

This thesis, entitled “**The three Empirical Essays on Environmental Economics**” prepared by **Zeeshan Malik** has been accepted as a doctoral thesis in accordance with the rules and regulations required for the degree of doctoral in social policy at Ankara Yildirim Beyazıt University, institute of social sciences, department of social policy by unanimous vote.

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PLAGIARISM

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To my late Grandfather Babu Minzar Hussain and my Family...

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ABSTRACT

This thesis contains three empirically estimated studies on the environmental economics of underdeveloped, developing, and developed countries. The first chapter of this thesis establishes the long run association between gross domestic product (GDP) and gross fixed capital formation (GFCF) with carbon emission (CE) in BRICS-4 countries and USA. To empirically estimate the long run cointegration and to check the validity of EKC hypothesis, the novel second-generation panel data analysis is done by taking the annual data from 1991-2020. All the variables are cross-sectionally dependent, differenced stationary, and cointegrated over the long run, according to the empirical estimations. Additionally, the calculation of coefficients using the DCCE approach revealed that the USA and the BRICS-4 countries accept the validity of the EKC hypothesis.

The second chapter of this thesis examines the effects of the unemployment rate, consumption of renewable energy, and oil rents on the G-20 countries' annual emissions of greenhouse gases from 1991 to 2020 using second-generation panel data analysis. This chapter's primary goal is to examine the G-20 nations' acceptance of the EPC theory. All the variables are cross-sectionally dependent, differenced stationary, and cointegrated over the long run, according to the empirical estimations. Also, DCCE estimates found that the unemployment rate and greenhouse gas emissions are negatively related. Therefore, the EPC hypothesis is validated. Moreover, findings also reveal that GHG is negatively related to REC and positively related with OR, respectively.

The third chapter studies the impact of environmental tax (Etax), GDP, and air-pollution effects (APE) on the GFCF of EU-16 countries by taking the annual data from 1991-2020 through second-generation panel data analysis. All the variables are cross-sectionally dependent, differenced stationary, and cointegrated over the long term, according to the empirical estimations. Additionally, it is discovered that GFCF and GDP have a positive relationship. Moreover, the environmental tax is estimated to be negatively related with GFCF in EU-16 countries.

Keywords: Environmental Degradation, Economic Growth, Unemployment Rate, Environmental Taxation, Second-Generation Panel Data Analysis.

ÖZET

Bu tez, az gelişmiş, gelişmekte olan ve gelişmiş ülkelerin çevre ekonomisi üzerine ampirik olarak incelenmiş üç çalışmayı içermektedir. Bu tezin ilk bölümü, BRICS-4 ülkelerinde ve ABD'de gayri safi yurtiçi hasıla (GSYİH) ile gayri safi sabit sermaye oluşumu (GSSEO) ile karbon emisyonu (KE) arasındaki uzun vadeli ilişkiyi ortaya koymaktadır. Uzun vadeli eş bütünleşmeyi ampirik olarak tahmin etmek ve EKC hipotezinin geçerliliğini kontrol etmek için, yeni ikinci nesil panel veri analizi, 1991-2020 yılları arasındaki yıllık veriler alınarak yapılır. Ampirik tahminler, tüm değişkenlerin kesit bağımlılığına sahip olduğunu, durağan olarak ayrıldığını ve uzun vadede birbirine entegre olduğunu bulmuştur. Ayrıca, yeni DCCE yöntemi ile katsayıların tahmin edilmesi, EKC hipotezinin BRICS-4 ülkelerinde ve ABD'de geçerli olduğu sonucuna ortaya çıkarmıştır.

Bu tezin ikinci bölümü, işsizlik oranının, yenilenebilir enerji tüketiminin ve petrol rantlarının G-20 ülkelerinin sera gazı emisyonları üzerindeki etkisinin, 1991-2020 yılları arasındaki yıllık verileri ikinci nesil panel veri analizi yoluyla alarak incelenmesini ele almaktadır. Bu bölümün temel amacı, G-20 ülkelerinde EPC hipotezinin geçerliliğini kontrol etmektir. Ampirik tahminler, tüm değişkenlerin kesit bağımlılığına sahip olduğunu, durağan olarak ayrıldığını ve uzun vadede birbirine entegre olduğunu göstermektedir. Ayrıca, DCCE tahminleri işsizlik oranının ve sera gazı emisyonlarının olumsuz ilişkili ters orantılı olduğunu bulmuştur. Bu şekilde, EPC hipotezi doğrulanmıştır. Ayrıca, bulgular sera gazının sırasıyla REC ile ters orantılı ve OR ile doğru orantılı olduğunu ortaya koymaktadır.

Üçüncü bölüm, 1991-2020 yılları arasındaki yıllık verileri ikinci nesil panel veri analizine kadar alarak çevresel vergi (Etax), GSYİH ve hava kirliliği etkilerinin (HKE) AB-16 ülkelerinin GSSEO'si üzerindeki etkisini incelemektedir. Ampirik tahminler, tüm değişkenlerin kesit bağımlılığına sahip olduğunu, durağan olarak ayrıldığını ve uzun vadede birbirine entegre olduğunu bulmuştur. Ayrıca, GSYİH ve HKE'nin GSSEO ile doğru orantılı olduğu bulunmuştur. Ayrıca, çevre vergisinin AB-16 ülkelerinde GSSEO ile ters orantılı olduğu tahmin edilmektedir.

Anahtar kelimeler: İklim Değişikliği, Ekonomik Büyüme, İşsizlik Oranı, Çevresel Vergilendirme, İkinci Nesil Panel Veri Analizi.

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LIST OF ABBREVIATION

AMG	: Augmented Dickey-Fuller
APE	: Air Pollution Effect
ARDL	: Autoregressive Distribution Lag
ASEAN	: Association of Southeast Asian Nations
BP	: British Petroleum
BRIC	: Brazil, Russia, India, China
BRICS	: Brazil, Russia, India, China, South Africa
CADF	: Cross-Sectional Augmented Dickey-Fuller
CCEMG	: Common Correlated Effect Mean Group
CD	: Cross-Sectional Dependence
CIPS	: Cross-Sectional Augmented IPS
CO ₂	: Carbon Dioxide
COP	: Conference of the Parties
CRE	: Correlation Random Effect
CS-ARDL	: Cross-sectional Autoregressive Distribution Lag
CUSUM	: Cumulative Sum
CUSUMQ	: Cumulative Sum of Squares
DCCE	: Dynamic Common Correlated Effect
DH	: Durbin-Hausman
DOLS	: Dynamic Ordinary Least Squares
DSGE	: Dynamic Stochastic General Equilibrium
ECT	: Error Correction Term
EDGAR	: Electronic Data Gathering, Analysis, and Retrieval System

EF	: Ecological Footprint
EIA	: International Energy Agency
EIF	: Energy Efficiency Index
EKC	: Environmental Kuznets Curve
EPC	: Environmental Philips Curve
EPS	: Environmental Policy Stringency Index
ET	: Environmental Taxes
EU	: European Union
FD	: Fiscal Decentralization
FFEC	: Flowing Fluid Electrical Conductivity
FMOLS	: Fully Modified Ordinary Least Squares
G7	: Group of Seven
G20	: Group of Twenty
GCC	: Gulf Cooperation Council
GDP	: Gross Domestic Product
GDPC	: Gross Domestic Products Per Capita
GFCF	: Gross Capital Formation
GMM	: Generalized Method of Moments
HQ	: Hannan-Quinn
IPAT	: Environmental Impact, Population, Affluence, Technology
IPS	: Im-Pesaran-Shin
LM	: Lagrange Multiplier
LMDI	: Logarithmic Mean Divisia Index
M&A	: Mergers and Acquisitions

MEA	: Mean Absolute Error
MENA	: Middle East and North Africa
MEPE	: Mean Absolute Percentage Error
MEPS	: Market-Based Environmental Policy stringency Index
MES	: Mean Squared Error
MINT	: Mexico, Indonesia, Nigeria, Turkey
NAFTA	: North American Free Trade Agreement
NMEPS	: Non-Market Environmental Policy Stringency Index
NO _x	: Nitrogen Oxides
OECD	: Organizations for Economic Cooperation and Development
OLS	: Ordinary Least Squares
OPEC	: Organization of Petroleum Exporting Countries
PHH	: Pollution Heaven Hypothesis
PMG	: Pooled Mean Group
PP	: Phillips-Perron
PVAR	: Panel Vector Autoregression
R&D	: Research and Development
RE	: Renewable Energy
REC	: Renewable Energy Consumption
REER	: Real effective Exchange Rate
SDG	: Sustainable Development Goal
SO _x	: Sulphur Oxide
STIRPAT	: Stochastic Impact by Regression on Population, Affluence and Technology
TO	: Trade Openness

UNCCD	: United Nations Convention to Combat Desertification
UNP	: Unemployment Rate
UNSD	: United Nations Statistics Division
UNTCTAD	: United Nations Conference on Trade and Development
VECM	: Vector Error Correction Model
WB	: World Bank



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1. INTRODUCTION

Climate change has been the highly discussed issue in the recent past of the socio-economic arena of the world. Neo-classical economic policies have faced a lot of criticism from the experts for growing the world economy at the cost of economic degradation. One of the important factors that has been assigned as the main reason for the climate change is the rate at which carbon emissions is occurring. The environmentalists argue that if the current economic policies continue to be implemented, then in the long run it is going to cause more harm to the world economy than the development it promises. One of the main factors other than harming limited resources is the human health effect of carbon emissions which is termed as Air Pollution Effects. Therefore, based on the current scenario, policy experts are stressing on the fact that unchecked growth policies are degrading the environment at a larger scale and its effects have started to show in the form of global warming, climate change, lowering mortality rates, increasing respiratory diseases, jobless growth, increasing unemployment, and decreasing life expectancy etc., meaning an overall damaging of human and natural resources. Thus, it has now become a discussing point on how to balance these aspects and take the world economy to a greater level of development without damaging the future of life and property. Hence, economic experts have posited the adoption of several environmental economics policies such as the adoption of renewable energy consumption, environmental tax policies, and to discourage the use of fossil fuels and over dependency of revenue from oil sales, the oil rents are advised to be monitored. Also, “Governments sometimes use environmental tariffs to influence the relative costs of various goods and services.” (OECD, 2022), to suppress the demand of mentioned goods and services which are a production of environment non-friendly industries and policies. In a nutshell, the sustainable development policies mainly stressing on, reduction of carbon emission, investment spending in environmentally friendly technologies, encouragement of renewable energy consumption, monitoring the air pollution effects of human health and oil rents, and soaring unemployment rate despite high-paced economic development.

Based on the country categories used to represent the world economy, these groups include nations like India, China, and the United States that are among the top producers of carbon emissions. Also, the G-20 member countries which are grouped as, “Argentina,

Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, the United Kingdom, the United States, and the European Union” having largest share of the world production of goods and services. Additionally, the EU-16 nations, which include, “Austria, Belgium, France, Finland, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Spain, Sweden, and UK”, consumes the highest share of world produce. Therefore, it would be highly rational to devise the model of these country groups to empirically study the global environmental economics.

This study contains three empirical studies in the field of environmental economics for BRICS-4 and USA, G-20, and EU-16 countries. The first essay of this study, titled, “The EKC Hypothesis Revisited in BRICS-4 and USA Countries: In "A Second-Generation Panel Data Analysis," which uses an innovative panel data approach and annual data from 1991 to 2020 to empirically examine and investigate the effects of economic growth and investment spending on carbon emissions in the BRICS-4 and USA countries, the Environmental Kuznets Curve hypothesis is tested. The study uses second-generation panel data approaches for empirical estimations while taking into account the series' cross-sectional dependence. Thus, to obtain reliable results, along with first-generation panel data techniques, we employ CIPS & CADF tests for panel unit roots test. For cointegration test, we adopted, Westerlund (2007) cointegration technique. For testing the heterogeneity problem, we employed Homogeneity test. Thus, considering these problems of CD and heterogeneity we adopted Dynamic Common Correlated Coefficients (DCCE): Using the Mean Group and Pooled Mean Group methods, the long run coefficients are estimated. The fact that this article included gross fixed capital creation as an economic indicator to verify the EKC hypothesis in the BRICS-4 nations and the USA, in addition to gross domestic product, is one of its major contributions. As per our knowledge, the previous studies have failed to consider the importance of investment spending (gross fixed capital formation). Moreover, the adoption of the novel DCCE method, the results obtained makes our study more reliable than previous ones.

The second essay of this study, titled, “The EPC Hypothesis Revisited in G-20 Countries: An analysis of second-generation panel data” explores empirically how the utilization of renewable energy, the unemployment rate, and oil rents affect greenhouse gas emissions of G-

20 countries between 1991-2020 by employing the novel second-generation panel data techniques and checks the validity of Environmental Phillips Curve hypothesis. Also, this study checks the cross-section dependency, employs CIPS and CADF tests to confirm differenced stationarity and employs Westerlund (2007) cointegration test to establish the variables' long-term relationships. Additionally, the DCCE method, which is the core of our study is used to estimate the long run coefficients of our model to ensure the accuracy of the estimates. Furthermore, the main contribution of this chapter is that it considers checking the validity of the newly established; the novel EPC hypothesis in the country groups (G-20) which is experiencing the higher unemployment rates, by employing the most superior empirical techniques. In addition, the previous studies on EPC hypothesis are very limited and this chapter, therefore, will be a valued addition in this field.

The third essay of this thesis, titled, “The Nexus between Gross Fixed Capital Formation, Environmental Tax, and Air Pollution effects in EU-16 countries, empirically calculates the effect of environmental taxes and air pollution effects on investment spending or gross fixed capital formation for the EU-16 countries using a second-generation panel data technique. To the best of our knowledge, the main contribution of this chapter is that it has considered the two very distinct explanatory variables and establishes the nexus between, environmental tax, air-pollution effects, and gross fixed capital formation. This chapter essentially serves as the definition of our thesis because it takes into account both the EKC hypothesis and corrective environmental policy at the same time, taking into account the fact that environmental taxes work in industrialized nations. So once more, to the best of our knowledge, this is the first study of its sort to be carried out utilizing such superior empirical methods.

The structure of the thesis is as follows: The introduction is in Chapter 1, and three different empirical essays are in Chapters 2, 3, and 4. Each essay includes, introduction, theoretical framework, literature reviews, data and modelling, methodologies, empirical results, and conclusions. Lastly, the Chapter 5 of this thesis provides the overall conclusion of this thesis and recommendations based on it.

2. THE EKC HYPOTHESIS REVISITED IN BRICS-4 COUNTRIES: A NOVEL PANEL DATA ANALYSIS.

2.2. Introduction

The deteriorating environmental circumstances have massively increased concern about climate change and global warming, highlighting the connection between expanding energy use, pollution, and economic growth. Even though global warming is caused by anthropogenic gas emissions, the repercussions vary by country due to socioeconomic and environmental factors, which were found the main cause of global warming climate instability (Houghton, 1996). The United Nations Framework Convention on Climate Change's most recent accord (UNFCCC) digital Conference in Glasgow 2021, known as Paris Agreement drew unprecedented contribution from world leaders to achieve consensus by 2020-2030 on legally requisite greenhouse gas emission reductions of methane up to 30% and other gases up to 50% to safeguard the environment for both the present and future generations by taking action that might greatly increase the economic sustainability (Michaelowa, 2021).

A data release by International Energy Agency draws eyes opening attention towards carbon emission and other energy related greenhouse gas emission over the past years. The Global emission of carbon only from energy incineration and industrial progressions reflections in 2021 were noted the highest ever increase in annual rate of carbon release in decade. Only in 2020 to 2021 a 6% increase causes 36.3 gigatons (Gt) releases in carbon emission due to the increment in global economic production by 5.9% which were noted as the highest amount carbon emission with GDP growth since 2010 results were based on region-by-region, fuel-by-fuel energy consumption (IEA, 2021).

Rise in global warming and climate change brought attention of the world to combat and discuss the global environmental issues. Air pollution, change in ocean temperature, disappearance and melting of glacier, delay in seasons effecting global average rise in sea level are several concrete evidence of global warming. The Paris agreement has decided to cope the climate change under the banner of international treaty on climate change due to the global increase in carbon emission. Which were functionally adopted by 196 countries to fight against

increasing climate change under the banner of National Determined Contributions (NDCs) to cut the global emission by 45% from 2019 to 2030 as zero-carbon solutions (UNFCCC, 2021). The primary focus was to adopt and implement the best available technologies to achieve economic and social transformation for future generations.

The novel COVID-19 pandemic has impacted the economy globally and emission caused by human were affected the rise of anthropogenic emission in early mid of 2020. Therefore, the report of EDGAR 2020 noted a decline trend in carbon emission by 5.1% lower (Monica et al, 2021). According to Emission Database for Global Atmospheric Research (henceforth, EDGAR) world largest carbon emission released in total by these 6 major world economies (such as, China, USA, EU27, Japan, India, and Russia), were 66.7% global fossil fuel related carbon emission emitted in total where the global share of GDP is 61.8%, while total global fossil fuel consumption noted as 65.2% in 2020. During the COVID-19 pandemic an increasing trend of carbon emission in China was noted at 30.34%, while others noted a decrease, like, USA at 9.9%, the EU27 at 10.6%, India at 5.9%, Russia at 5.8%, and Japan at 6.8% decreases their emission respectively (Monica et al, 2021). The crux of the discussion, how high-polluting economies might decrease GHG emissions without impeding their productivity expansion has been discussed at the Cancun 2010 Conference on Climate Change. The primary energy consumption by fuel of world largest 6 countries show a decreasing trend from 2019 to 2020 noted as, where China (26.1%), USA (15.8%), EU27 (10%), India (5.7%), Russia (5.1%) and Japan (3.1%) (BP, 2020).

From the statistical discussion above these countries are of the largest carbon emitter in the world which a largest of the world economy as well. Therefore, it will be reasonable to check the EKC hypothesis in these countries by assembling their data. Moreover, the investment spendings defines the future production therefore, along with gross domestic product, we must consider the relationship between gross fixed capital formation and the carbon emission in the light of EKC hypothesis as well.

The purpose of this study is to investigate the impact of carbon emission on the economic growth performance among the selected countries. Various researchers examined the effect of economic growth on carbon emissions in various nations because of the increase in carbon emissions, but their studies did not come to the same empirical conclusions. The reason for this

non-similarity can be because of different economic level of the countries or the different types of statistical modes which have been used in previous studies. Thus, the main reason of this study to find the precise empirical results based on new research technique and methods. Main aim of this chapter is to identify the relationship between economic growth and carbon emission under EKC hypothesis in BRICS 4 countries and USA which are largest emitter of carbon, as we saw in the discussion above. To understand the economic growth structure to emit the carbon emission at a different time scale is the main part of this chapter in the perspective of world climate change mitigation. To find the relationship between economic growth and carbon emission, the gross fixed capital formation as an important economic indicator is preferred. Since investment spendings defines the future production level which thereby defines the carbon emission level.

At (UNFCCC, 2017), USA, China, and India had agreed to reduce the green house emission by half till 2030 and the follow-up meeting were digitally organized in Poland 2020 (USA withdrew from that meeting), where growing economies requested to submit their report by 2023 of carbon mitigation policy implementation in both short and long run. Therefore, the importance of climate change and the rising economic growth at the expense of environment, were the main objectives of this research to be considered as an important player, especially on BRICS-4 countries and USA due to their unregulated economic growth and neglect of problem of carbon emission.

2.2. Theoretical Background and Framework

The section of the chapter addresses the theoretical foundations of environment degradation and economic expansion. Environmental pollution in the past decade raises the concerns of the world's thinktank to adopt the sustainable policies and technologies to cope and combat anthropogenic gas emission without any further damage of planet earth (Cook, et al., 2013). A pollution free and sustainable environment is the only gift to our future generations and species living on this planet, where they can live in a pollution free environment and enjoy their social and personal spaces in the coming years. The general idea of the EKC hypothesis is commonly applicable in a broad perspective literature to examine the effect of economic growth and capital formation on environment sustainability (Nasir & Rehman, 2011). After a certain

point, as per capita growth increases, environmental quality improves due to the gradual awareness brought through the application of environmental degradation regulations, improved infrastructure, advanced technology and investments in environmental education. Environmental degradation increases in parallel with increase in income level (Pedroni & Levinson, 2001).

A group of researchers started to emphasize on the study and subtleties between the level of income among countries and their anthropogenic gas emission. Whereas Grossman and Krueger's research of the North American Free Trade Agreement (NAFTA) in 1991 gave birth to the concept of the "Environmental Kuznets Curve" (Hervieux & Mahieu, 2014). Potentially the concept gains its recognition when the World Bank Development Report was release in 1992 (IBRD, 1992). Grossman and Krueger noted in their research paper titled as " North American Free Trade Agreement", they discovered that the concentrations of two pollutants, sulphur dioxide and smoke, increase with rising levels of gross domestic product per capita and low levels of national income while decreasing with high levels of per capita income and growth in gross domestic product. (IBRD, 1992).

WDR (1992) report titled as "Development and the Environment" was published in 1992. Research examines how environmental conditions are affected when an economy experiences both economic growth and development at the same time. The main objectives of the reports were focused on combined environmental contemplations in development policymaking. Thus, the report statistically stated that sustained economic and human development is conceivable and compatible with better ecological conditions, but that will require significant political, economic, and structural reforms. A multivariant policy is required to compensate the present condition. Therefore, the objectives of efficient income growth and environmental protection must be strongly advocated. Later, strong policy guidelines and frameworks should be implemented to encourage decision-makers to participate towards a less damaging anthropogenic gas emissions (Shafik & Bandyopadhyay, 1992). The EKC's versatile hypothesis is that changes in environmental consequences may be influenced by economic considerations, which, according to the direction of economic growth, could result in a rise or fall in environmental damage (Stern, 2004).

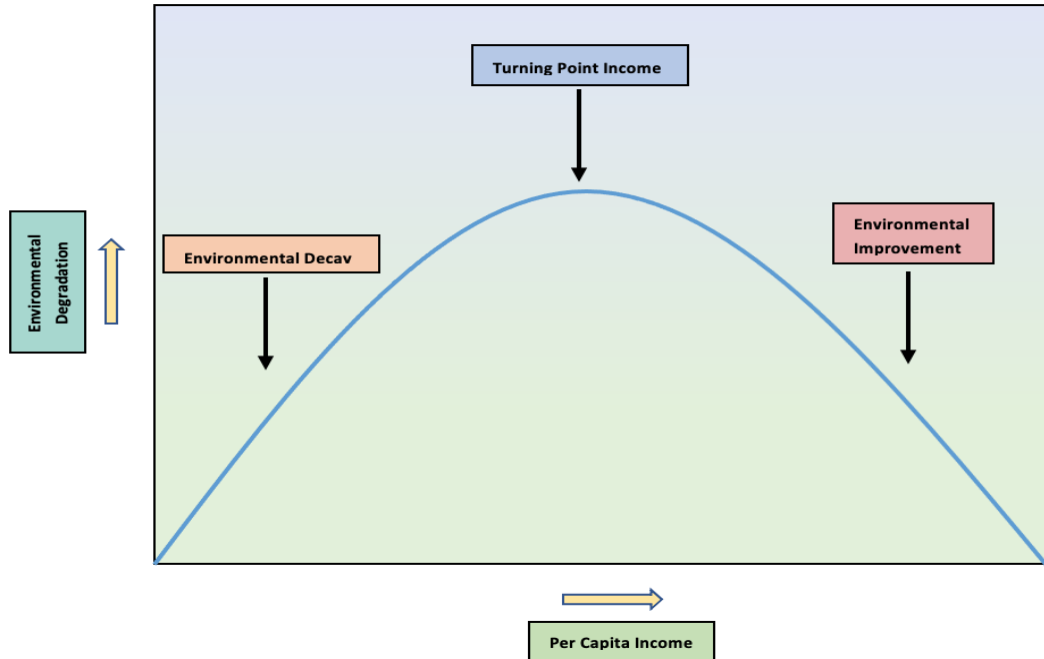
The common argument of the research indicated that in any economic development a decline in the early stage of environmental condition and recovers in further phase as economy grows. Likewise, the ecological pressure rises relative to income in the initial phases of development and then drops below gross domestic product as income increase. Developments in income and environmental standards are systematically correlated in a way called as "Environmental Kuznets Curve". Kuznets, who presented an alternate correlation between income inequality and economic growth, discovered the inverted U-correlation in 1995. The EKC relationship's theory is naturally influential. Although, due to industrialization, the population rises rapidly due to high emphasize priorities the material outcome and individual are more concerned towards job which provide income than that of healthy ecosystem (Dasgupta et al., 2002). A Speedy growth eventually effects in a rise in the use of fossil fuels (non-renewable energy) and environmental degradation, which creates further burden on the environment. Countries are either unfortunate to manage and pay attention towards pollution reduction or they are oblivious to the environmental impacts of growth only. Individuals are either does not have awareness to pay attention towards emissions reduction activities due to their income level or they do not have awareness towards impacts of growth on environment. Therefore, according to the EKC hypothesis, there is a powerful correlation between the intensity of economic activity and environmental degradation. Based on statistically verified indicators, EKC curves elaborated on the qualitative shift in environmental deterioration and how an economy or society will be impacted. Particularly, Environmental Kuznets Curve fundamentally two-dimensional empirical phenomena that enlighten the key features of collective human behaviour (Nasir & Rehman, 2011).

2.2.1. Theoretical Framework and the Background of the EKC

The study borrows the approach employed by (Wang et. al, 2011), (Ang, 2007) and the panel data analytical framework proposed by (Apergis & Payne, 2009). Following (Wang et. al, 2011), (Ang, 2007) and (Apergis & Payne, 2009), we established the long-term relationship between carbon emissions (GFCF) and gross fixed capital and gross domestic product (real GDP) in BRICS-4 countries and USA. Environmental Kuznets Curve hypothesis in its original form can be mentioned as follows:

$$E = f (X, Y, \Delta N) \quad (1)$$

In the above equation "E" represent as environmental indicator, "X" represent as an economics growth indicator, "Y" represent as a gross capital formation and " ΔN " represent as explanatory variable characteristics that might affect environmental degradation We did not include any other additional variables in our model because the primary objective of this research is to examine the causal link and cointegration between economic growth, gross capital formations, and carbon emissions. Figuratively, EKC curve is described as shown below. It shows that, initially, environmental degradation and economic growth are positively related, therefore we see an increasing graph up to optimum. Later, after the economic growth reach certain level, the environmental degradation begins to decline with further increase in output levels. Indicating that, with increase in income and output level of an economy, the through environmental protection policies and adoption of energy efficient technologies, the environmental degradation shows negative relationship with economic growth.



Source: Author Calculation

Figure 1. Environmental Kuznets Curve

The EKC hypothesis represent a profound dynamic process of change in income level of a country over a period as shown in figure above. Where level of anthropogenic gas emission goes up and after threshold limit of income start declining in long run. It's a trajectory of an economy that goes through multiple stages of development can be observed empirically with cross-economy and cross-sectional stats represents income groups response to pollution (Stern, 2004).

2.2.2. Historical Background of EKC

• The emergence of Environmental Kuznets Curve

It was observed that there was a u-shaped association between income inequality and per capita (Hao et al., 2016). Therefore, the distribution of income shift towards equality as economic growth pattern carried out, initially it has been noted rise in the patter of income inequality but has been settled in later. Although, developed countries has confirm that the rise in per capita income reduce the level of environmental degradation due to the awareness came with income towards pollution and healthy environment (Brannlund & Ghalwash, 2008). In case of developing and under developing economies sustainable globalization noted to be more efficient in generating per capita income and eradicating income inequality (Borghesi & Vercelli, 2013). Thus, EKC help to identify the impact of income inequality and environmental degradation among economies.

• Growth Controversy of Environmental Kuznets Curve

Growth controversy and strategies are the foundation of Environmental Kuznets Curve. Environmental degradation found to have an inverted U shape correlation with growth rate. Therefore, increase in growth rate reduces the impact of environmental degradation in any economic activity (Stem et al., 1996). Due to the allocation of less energy-inefficient consumption in income activities, theoretical and empirical features of EKC demonstrate that as income increases, the amount of environmental degradation decreases.

2.2.3. Factors Responsible for EKC

• Income Elasticity and Environmental Quality Demand

Individuals possess a higher standard of living as their earnings grows and they become more interested in the quality of the ecological system. This desire for a better environment may lead structural changes in the economy, which tend to lessen ecological damage (Roca, 2003). The most accepted justification for the structure formation of an EKC theory is that as a countries or societies living standard rise, people attach consideration to the priority for environmental services. As economic development accelerates with sustainable intensification and other resource exploitation, the rate of resource scarcity begins to significantly outpace the number of renewable resources, and pollution output increases in volume and intensity. At higher stages of development, environmental deterioration straightens out and steadily declines due to structural adjustments toward relevant data manufacturing and services, improved environmental awareness, the implementation of environmental legislation, better technology, and increased global spending. Thus, increasing per capital income rises the demand of pollution free environment, where elasticity of environmental standard identified and to keep it environmentally friendly with the income elasticity is less than one percent (Barbier et. al, 2017).

• Parameter for Technological and Composition Effects

(Stern, 2004) identified the economic growth effects on environmental level thus, it can simply evaluate under the shadow of these three parameters such as, scale effects, innovation implications, and structure implications are all three mechanisms through which economic growth impacts quality of the anthropogenic gas emission.

• Scale of Production: The intensity of mitigation efforts and gross emissions rate of return to capture rather than their absolute values depending on increasing prevention of scale of production alone does not cause pollution to decrease alongside income unless the reduction gains per scalability exceed the returns to gross pollution production. Therefore, theoretical evidence was noted down that increasing evidence of return to scale in reduction alone is not enough to pretend the output, but a supplementary focus required to examine the root cause of

gross pollution generation and investigating the reduction technologies (Plassmann & Khanna, 2006).

• **Innovation Implication:** Technological innovation in economic development led to the major transforms; from agricultural to heavy industrial technology. However, shifting to heavy industry increased the economic development and production but alongside, it brought more emission in the environment. Theory which demonstrates empirically that speedy industrial transformation in economic development contributed to emission, adoption of carbon-intensive product manufacturing industry reduces the level of emission and a trade-off for less carbon emission generating technologies with resource-intensive innovations was adopted to encourage less emission generating industry by allocating investment with R&D (Tian et al., 2014). Thus, investment in industrial innovation for heavy industry or importing emission-intensive technology is base foundation of EKC hypothesis.

• **Structure Implication:** Shifting and transformation of any economy to different policy and change in economic structure may affects the economy and can cause huge capital formation. (Bulte & Soest, 2001) constructed a model to understand the depletion of natural resources, therefore suggestion for global procurement of resource and shifting industries where sufficient resources available for manufacturing. Essential transformation in energy-intensive technology from coal to gas, fossil fuel to solar energy and wind energy and low sulphur coal to high sulphur coal has already contributed to the reduction of emission (Gielen et al., 2019). Structural implication significantly transforms the patter of heavy manufacturing industry to adopt less carbon-intensive technology for the efficient productivity and emission related transformation for sustainable economic development. Thus, depletion model for natural resource-intensive consumption were developed to obtain the EKC hypothesis.

• **International Trade**

International trade played a very important role in EKC hypothesis and found that trade increases the economic development in an economy. Therefore, growing trade is a significant factory for creating emission in developing countries for production and consumption emission, non-energy-intensive manufacturing and production of trade goods and services (Peters et al., 2011). Thus, through monitoring emission transfer cause by international trade can stabilise the

global greenhouse emission. That's the reason for International Trade to be the major player of EKC hypothesis in sustainable emission.

- **Foreign Direct Index**

Foreign direct investment played one of the major roles in any developing or under developing economy to combat anthropogenic gas emission. To attract FDI, developing economies can drop and regulate their environmental standard to create a pollution heaven (Gokmenoglu & Taspinar, 2016). Therefore, developing countries are dependent on emission-intensive and resource-intensive technologies from developed economies or institutions which FDI brought into the economy. Thus, rising international concern for sustainable greener product and the connecting of economic cooperation to ecological problems has the potential to impact the flow of these investments. FDI has major role and opens the space of EKC hypothesis for research.

- **Role of Economic Agents**

International and national non-governmental organizations, financial institutions, industrialist, investors, environmental activist, environmental regulator, policy maker and citizens can make a huge impact to adopt carbon-intensive policies to combat harms caused by growth of emission (Pearse & Bohm, 2014). All the mentioned actors can play a very critical role in the adoption of carbon-intensive technologies and products by refusing the services and product causing more emission comparatively to economic growth. Economic agents played to the major player of EKC hypothesis in sustainable emission.

2.2.4. Impact of Carbon Emission on Various Economic Indicators

- **Economic Growth vs Carbon Emissions**

Azam et al (2016) according on their empirical estimations, it was discovered that energy use and carbon emissions significantly harmed economic growth. Therefore, specialized, and strict measures are required to regulate pollution levels resulting from sources other than the consumption of liquefied fuel, according to empirical estimates of the research work. As a result,

lowering pollution levels will ultimately increase social welfare and sustainable economic growth.

Al-Mulali & Sab (2012) researchers determined that the carbon emissions had a considerable adverse effect on energy use and economic growth based on their empirical findings. According to study, this indicates that an increase in economic activity is leading to a greater emission of carbon. As a result, empirical analyses of the research concentrated on developing sustainable energy sources to lower carbon emissions. The study's conclusions thus opened the door to reducing the effects of carbon emission levels by concentrating on sustainable energy investment to achieve sustainable economic growth.

Income Inequality vs Carbon Emissions

Wan et al (2022) since it was discovered that rising shares of low-income sets are the primary driver of higher CO₂ emissions while rising shares of high-income sets contribute to lower emissions, the authors of the study hypothesize that there is an interaction between income inequality and carbon emissions. Additionally, growing wealth inequality can reduce energy use and boost R&D spending, which will help to reduce CO₂ emissions.

Halicioglu (2009) concluded in the study that there exists an interchangeable between income inequality and carbon emission. Furthermore, it was shown that rising income levels are contributing to an increase in carbon emissions, but declining economic activity will result in higher unemployment and lower income. Therefore, increasing investment and imports in sustainable pollution control methods while lowering the initial cost can aid in lowering the level of carbon emissions without.

• Per Capita Income vs Carbon Emissions

Li & Lin (2013) study's findings led to the conclusion that per capita income significantly reduced carbon emissions. The effect of GDP per capita on carbon emissions was thus found to vary across various socioeconomic groups. As a result, carbon emissions rise along with income level, but they start to decline after income influxes reach a certain threshold.

• FDI vs Carbon Emissions

Xie et al (2020) stated that foreign direct investment had significant positive impact in reduction of carbon emission in the model countries. Therefore, influxes of FDI open area for emerging economies and thinktank industries to participate in international markets, where heavy industries need more energy, more energy means burning more fossil fuel and more fossil fuel means release in carbon. Thus, the endorsement of greener, sustainable energy usage and sustainable fuel consuming technologies with strict tax policies can heavily impact on carbon release.

• Energy Consumption vs Carbon Emissions

Salahuddin et al (2018) observed that increasing demand of energy consumption is causing and impacting negatively on carbon emission. Wherein, to mitigating increasing demand of energy consumption with green, cleaner, and sustainable energy noted decline in carbon emission rate. Thus, suggested that the expansion of forest, capitalization clean energy, reducing taxes and subsidies with high investment in energy technologies lead to a sustainable energy consumption with less carbon release level.

• Balance of Trade vs Carbon Emissions

Balance of trade essentially based on import of the products which is the main cause of carbon release in exporting countries. (Ahmad et. al, 2021) noted that the balance of trade is impacting positively on carbon emission on under developing and developing countries. Therefore, aggregate economic output strongly contributing to balance of trade through environmental sustainability technique. Thus, adoption of latest ecological sustainable industry where clean energy could play an important role in decreasing level of carbon emission by allocation and distribution of less carbon releasing product manufacturing among

• Poverty vs Carbon Emissions

Carbon emission disproportionately affects cognitive development, emotionally, educationally, children's health and socially for underdeveloped and developing countries according to Gini coefficient around the world. Baloch et al (2020) asserted that there was a

negative correlation between poverty and carbon emissions. Due to their ongoing struggles with eradicating poverty and environmental pollution, developing and underdeveloped countries require more attention from international think tanks. Thus, it was inferred that the increase in income level rise helps in alleviating the poverty and adoption of sustainable energy with environmental regulations can decrease in carbon release, which requires strong steps to adopt sustainable development goals.

• Human Capital vs Carbon Emissions

The development of human capital is associated with an improvement in environmental quality brought about by a decrease in carbon emissions. Yao et al (2020) stated that the human capital standard is directly negatively impacting carbon emission and environmental pollutions. Moreover, living standard, health and opportunities of equal wage and work and equal distribution of capital are the main issues of pollution among under developing and developing countries. Thus, investing in education, creating employment opportunities, seasonal training and seminars helps in building a healthy and sustainable society to combat the environmental issues of pollution.

• Human Development Index vs Carbon Emissions

Yumashev et al (2020) study focused on human development index impact on carbon emission and found that the HDI has been a major factor and impacting on carbon emission depending on the GDP and research and development expenditure. Furthermore, major factors which are responsible for carbon emission among countries of different economics growth were pin down as level of higher education, influence of clean and sustainable energy consumption in population and industrial sector. Thus, adoption of sustainable strategies and sustainable energy consumption, awareness about higher education and investment in R&D promote the increase in HDI level, which in reverse will positively improve the level of carbon emission release.

• Life Expectancy vs Carbon Emissions

Wang et al (2021) in their study they noted that there is a trade-off between life expectancy and carbon emission since it was found that urbanization cause for higher CO₂

emissions which cause rise in unemployment level, population density and lower economic growth rate while increase in growth rate contribute to lower carbon emission. Moreover, rising in sustainable strategies and employment opportunities increase the growth rate which can decrease the degree of aging and increase life expectancy among the low-income groups, which means in turn help to decrease CO2 emissions.

Table 1. Summary of Impact of Carbon Emissions on Economic Indicators

Authors	Research Object	CO2 vs	Impact
Al-Mulali & Sab (2012)	Sub Saharan African countries	Economic Growth	Negative
Azam et. al (2016)	China, USA, India & Japan	Economic Growth	Negative
Halicioglu (2009)	Turkey	Income Inequality	Interchangeable/Trade-off
Wan et all (2022)	217 countries	Income Inequality	Interchangeable/Trade-off
Li & Lin (2013)	110 countries	Per Capita Income	Positive
Xie et. al (2020)	Emerging 11	FDI	Positive
Salahuddin et. al (2018)	Kuwait	Energy Consumption	Negative
Ahmad et. al (2021)	Pakistan	Balance of Trade	Negative
Baloch et. al (2020)	Sub-Saharan African countries	Poverty	Negative
Yao et. al (2020)	20 OECD Countries	Health or Human Capital	Negative
Yumashev et. al (2020)	28 OECD countries	HDI	Negative
Wang et. al (2021)	154 countries	Life Expectancy	Negative

2.3. Literature Review

The Environmental Kuznets Curve (EKC) and economic growth literatures were utilized to demonstrate a link between carbon dioxide emissions, GDP (\$) growth, and real output (Kuznets, 1955). The literature on real GDP (\$), carbon emissions, and economic growth is organized by (Magazzino, 2014b). However, the Electricity demand-GDP nexus is outlined in (Magazzino, 2014a) and (Payne, 2010).

Magazzino (2014) The relationship between Economic Growth, CO₂, and EC within the 6 ASEAN countries from 1971 to 2007 is examined using a VAR panel technique, emphasizing the statistically substantial positive response of Economic Growth and Energy. Meanwhile researcher found that: Real GDP per capita exhibits forecast error caused primarily by energy use. Due to the shift in the equation's mode from 10 steps, the error variance in the GDP and carbon dioxide equation volatilities is minor. Where finding demonstrates that the "Growth Hypothesis" foothold for this panel study was proved by the statistical analysis of the VAR and IRFs for the estimated sample data. Study indicated that 19% Carbon Dioxide Discharges equations account for 40% of the error variance in CO₂ calculations, whereas controls from shocks to the GDP equation were 21%. The six ASEAN countries' substantial increases in energy consumption and carbon dioxide emissions skewed their actual GDP. where the handling of energy was affected only by modifications to the statical equations. Between 1971 and 2017, it was discovered that there was a positive correlation between the calculated coefficients and impulse responses between economic growth, carbon dioxide emissions, and energy use.

Murshed et al. (2020) in South Asia from 1980 to 2016, "cross-sectionally dependent heterogeneous panel data with structural breaks" were used to examine the EKC hypothesis for the consumption of liquefied petroleum gas. To evaluate the relationship between GHG emission, liquefied petroleum gas, FDI, trade openness, and GDP for the EKC hypothesis, the researchers used the CCMG and AMG model technique. The research's empirical findings support the EKC theory, and as a result, CCMG and AMG estimates found that LPG use significantly increases greenhouse gas emissions across all economies. Thus, considering LPG as changing and combating factor in South Asian countries for anthropogenic emissions which can help the economic growth further in the direction and hypothesis presented by EKC curve. The main focus and policy recommendations of the empirical findings focused more on LPG

energy consumption and technological innovation, FDI considered to be an important player for the latest and modern carbon emitter technologies for a sustainable economic development in that region.

Cheikh et al. (2021) employing the EKC framework, this study examines the nonlinear correlations between energy use, CO₂ emissions, and Level of income within 12 MENA nations between 1980 and 2015. The empirical model employed was PSTR to understand the relationships among, CO₂, income level as GDP proxy, EC. Therefore, empirical estimates obtained were indicated the validity of EKC hypothesis in MENA countries. Moreover, PSTR estimates were significant and indicated the energy consumption impact on CO₂ depends on income level with another point that the energy intensive activities do not fall under the phenomenon of growth and development in an economy. Thus, the research concluded that the emission in an economy depends on the level of income and energy consumption in an economy. Considering the MENA countries, policies and adoption of advance carbon free technology and flow of foreign direct investment could play a vital role.

Pandey & Mishra (2016) did a study to examine the relationship between SAARC countries' economic growth and carbon emissions using the "panel VAR approach. The panel unit root test, panel cointegration test, panel VECM employing (IRFs) and (VDs)", and the analysis covered the years 1972 to 2010. They found that the IRFs and VDs had a positive impact on GDP and CO₂ emissions in the opposite way (GDP). The estimates of the cointegration test were statistically significant with 0%, wherein, the co-integration equation found that with 1% increase in GDP is causing 1.83% decrease in Carbon emission. furthermore, it suggests that Granger Causality between the study's variables is necessary. Since GDP and CO₂ are panel non-stationary after panel unit testing, the Granger causality method revealed that Economic Growth and Carbon Release (CO₂) have unidirectional causality with 5% when there is a statistically significant difference of 1% between the two variables, the null hypothesis of non-stationarity is rejected. Economic expansion hurts the ability to release carbon, according to research, but it does not cause it. Study refutes the Environmental Kuznets Curve Hypothesis of SAARS countries, which states that because these nations are developing and underdeveloped, economic activity in those nations has a negative influence on carbon

emissions. To combat carbon emissions and promote environmental sustainability, researchers advised adopting energy-intensive and renewable energy policies.

Usman & Jahanger (2021) for 93 nations between 1990 and 2016, research was done on the varied effects of remittances and institutional quality in the reduction of the environmental deficit under the notion of the EKC hypothesis. They have adopted an empirical model approach of panel quantile regression (henceforth: PQR) to analyze the ecological footprint, institutional quality index, energy utilization, GDP, FDI, trade openness, FD, and urban population. The EKC hypothesis is supported by the empirical estimates for the panel. The empirical estimates of the PQR model, indicated the significant and positively effects on environmental degradation by the inflow of remittances, GDP. Thus, the finding considered the policy in favor of remittances for eco-friendly industries, technology, institutional quality, and use of renewable energy with advanced research and development policy.

Liu et al. (2019) conducted research on 125 countries to analyses the export diversification, CO₂ emission and EKC over a period of 2000-2014. They have used export diversification (CR, CSCEEF AD), GDP and CO₂ variables for Fixed effect model (FEM) for high-income level, REM for low-income level and OECD countries. EKC hypothesis were found valid for the panel. The FEM an REM estimates noted that negative relationships indicating that export diversification export products diversification both improve the pollution level for panel. Thus, it was denoted that the focus on export diversification and product diversification pollution is needed to be considered to reduce the emission level in both OECD and low-income level countries, where investment in the direction of emission free technology for energy could play important role, further research in the dynamic econometric methodologies needs to be considered.

Akdiri et al. (2021) conducted research on an economic freedom verses economic development perspective within BRICS for the period of 1995-2018. They have adopted an empirical approach of PMG-ARDL to analyze the GDP, CO₂, economic freedom, HDI, Coal, natural gas, and oil. Therefore, their empirical estimates validate the EKC in BRICS for long-run. The PMG-ARDL estimates denoted economic freedom is significantly and negatively related to emission. Thus, they have concluded that while economic expansion may, in the short term, raise emissions, it may also contribute to long-term increases in income levels and

economic development. To gain the sustainable economic development economic freedom could have an important role in economic development, increase in income level bring awareness towards the emission free products and industry.

Yigiti (2021) conducted association between economic growth and environmental degradation in the D8 countries between 1990 and 2014 was studied. The RGDPPC were investigated using panel VAR analysis to determine the relationship between carbon release and energy consumption. The Pedroni (1999) "Cointegration test" was performed by researchers to examine the cointegration between the variables utilized in the study. They discovered that the variables are stationary at the same stage when using the unit root test and inverted roots. Additionally, a multinomial econometric model was added to the unit root circle, which allowed Granger causality testing to replace panel VAR statistical analysis and led to the discovery of a one-way causal link between energy usage, carbon emissions, and real GDP. Researchers also found that the D8 countries' energy use and carbon emissions support economic growth, and they recommended creating long-term sustainable energy consumption policies.

Silva et. al (2012) used the SVAR approach to examine the effects of renewable energy sources on economic growth and CO₂ emissions using GDP, CO₂, and RES-S variables with the same economic framework but different economic and social growth in 4 different countries for the period of 1960–2004 with the same policy of investment in renewable energy sources. Apart from one country, statistics clearly demonstrated in impulse response functions that the increase in renewable energy sources affected economic growth in terms of GDP per capita with a decrease in carbon release per capita. This was done to test whether the variable was stationary. Researcher adopted a distinct analyses approach which were incomparable to other studies at that time span. The results were controversial due to every country sustainable energy policy, where sustainable technology in renewable energy generation needs more area to be explored for cost cutting which can be beneficial to economics activities and decrease in carbon release. A panel study could have an implacable addition to the research for that cortex area of renewable energy sources.

Saboori et. al (2012) conducted a study in Malaysia to examine the connection between economic growth and CO₂ emissions: To examine the long-term causal link for the years 1980 through 2009, the environmental Kuznets Curve hypothesis underwent a cointegration analysis.

Time series annual data from the USEIA (U.S. Energy Administration) were used in the analysis for CO₂ and real GDP per capita from the World Development Indicator. Granger's causality test was applied to two variables to test the Autoregressive Distribution Lag (ARDL) for a causal connection. The Environmental Kuznets Curve (EKC) the study's actual results, which showed a long-term connection between per capita Carbon release and real GDP, confirm the theory. As a result, the Granger Causality test based on the VECM model did not uncover any immediate evidence of a causal connection between carbon release and economic growth. As a result, it was found that there is a long-term, unidirectional causal relationship between economic growth and carbon release. A relationship in the U shape was found between the chosen variables in both the long run and the short run.

Mulali et. al (2015) evidence from 18 Latin American and Caribbean nations between 1980 and 2010 is used to analyse the Kuznets curve estimation for the environment Data from the World Development Indicator (WDI) for (GDP, renewable energy consumption) & Energy Information Administration (EIA) for (Carbon Emission). As a result, the Vector Error-Correction Model (VECM) was applied, and Kao integration tests revealed that four of the variables were cointegrated. The Fully Modified Ordinary Least Squares (henceforth, FMOLS) model was employed to examine the impact on the relationships between the log-runs of the selected variables. The EKC theory was supported by estimates from the FMOLS model that indicated an inverted U-shape link between GDP and carbon emissions. Moreover, it was found in long-run FMOLS estimates that the development in investment can advance quality of environment by diminishing Carbon release level. Therefore, in long-run renewable energy did not contribute to carbon release reduction. Hence, the Granger interconnectivity causality between GDP growth, renewable energy, financial investment, and carbon release was discovered to exist in both the long and short runs.

Lopez et. al (2015) did a study on the 1980–2025 period in Venezuela to investigate the Kuznets curve for the relationship between economic growth, CO₂ emissions, and the environment which was based on panel data with four distinct baseline scenarios that were predicted using historical data on the gross domestic product, energy consumption, and carbon emissions. *Kaya* identity model formation annex based on gross domestic product including used in the study to see how it affected renewable energy. Therefore, the relationship between

Carbon release and GDP were analysed which outcasted that the Venezuela will not fall under the perimeters of Environmental Kuznets curve hypothesis for further stage. Moreover, they formed a two-stage calibration for the model 1980-2010 and 2011-2025 data set to predict carbon release and sectoral energy consumption under the canopy of projected GDP. According to the study's findings, if sustainable energy development and GDP growth are combined, carbon emissions will decline by up to 50%. The analysis also shows that although Venezuela does not meet the Environmental Kuznets curve (thus, EKC) hypothesis under its current circumstances, its Gross Domestic Product and Carbon Release have a positive elasticity in the medium term.

Bilgili et. al (2016) forecasted research on how usage of renewable energy affects CO2 emissions dynamically: Using data from the years 1977 to 2010, a revised Environmental Kuznets Curve technique was used to estimate the model. The World Bank database was utilized to collect the annual time-series panel data for 17 OECD nations. Additionally, the estimates from the panel variance model, which rejected the null hypothesis of no cointegration, were employed. A panel unit root test was performed earlier to verify the data's stationarity. Additionally, the effect of the variables considered in the model on the association in the long run was examined using the cointegration of independent variables through the FMOLS and DOLS models. The FMOLS model's estimates revealed a negative association between the use of renewable energy and carbon emissions and a positive correlation between carbon emissions and GDP. The EKC hypothesis was thus proven to be essentially accurate for the 17 OECD nations. Individual nation data demonstrate that EKC can manifest in any nation, regardless of income level, and regardless of the size of the country's per capita GDP, a negative causal association between renewable energy utilization and the latter was discovered.

Ahmad et. al (2017) did a study titled Is There an Environmental Kuznets Curve? Modelling Croatia's between 1992Q1 and 2011Q1, CO2 Emission and Economic Growth were examined. Functional study criteria were covered by the Autoregressive Distributed Lag (hereafter, ARDL) and VECM techniques. The World Development Indicator (WDI) provided the quarterly statistics on carbon emissions, and the Economics Intelligence Unit provided the GDP data (EUI). The approach of the ARDL limits test was used to ascertain cointegration between the variables. As a result, it was identified and demonstrated that EKC is ultimately

quite legitimate for Croatia. Long-term adjustments will be made to restore the short-term equilibrium with a 5.3 percent quarterly basis, which is backed by a statistically significant negative error correction term (ECT). Finally, the VECM model supports the causation between carbon emissions and GDP in both directions. As a result, every finding was statistically significant and supports the long-term use of the EKC model in the Croatian economy.

Pao et. al (2011) comprehensive study on predicting and modelling Brazil's economic development, energy use, and CO₂ emissions from 1980 to 2007. Under the VECM technique, functional research criteria were covered. Annual data on energy usage, GDP, and carbon emissions were gathered from (WDI) and (EUI). The approach of the ARDL limits test was used to ascertain cointegration between the variables. As a result, it was discovered and demonstrated that EKC is highly legitimate. Energy use and income both worked, and a u-shaped relationship was discovered. In the long term, between the variables, a bidirectional Granger causality was found. Additionally, the Johansen's cointegrating equation's estimates showed that, when GDP is held constant, a 1% increase in energy consumption results in a 0.77% increase in carbon emissions.

Baltagi et. al (2019) forecasted research on economic activity and CO₂ emissions. a mean-field-variational bayes model to estimate the cubic spline smoothing model using data collected from 1991 to 2015, both a mixed-fixed and random-coefficients panel data model and a semiparametric panel data model with random coefficients were applied. The standardized World Income Inequality Database servers, the Emission Data for Global Atmospheric Research (EDGAR), the European Commission, the Joint Research Centre, the Netherlands Environmental Assessment Agency, the Eurostat database, and the European Commission were some of the sources used to estimate the model. The mean field variational Bayesian approximation was used to estimate a log model with structural breaks between to regulate variables including energy intensity and its uses, energy consumption, population density, urbanization, and trade, CO₂ release per capita and gross domestic product per capita were used. The findings support the growing but complex relationship between carbon release and gross domestic product by demonstrating a considerable elasticity between carbon emission and GDP of up to 1%. Therefore, the relationship between environmental pollution and economic growth is first, monotonically increasing, and then reducing for low levels of gross domestic product

per capita, according to estimates from the Mean Field Variation Bayesian (MFVB) model. Additionally, a semiparametric model for random variables was chosen rather than a parametric null hypothesis.

Cowan et. al (2016) research on the 1990–2010 time period's energy use, economic growth, and CO₂ emissions in the BRICS countries. The World Development Indicator's annual panel data for the BRICS countries was utilized (WDI). Using a panel causality model, this study examined the causative link between energy use, economic expansion, and carbon emissions. Therefore, the neutrality hypothesis applied to Brazil, China, and India whereas the conservation hypothesis applied to Russia and South Africa, according to the study's empirical evidence. Significantly, it was found that Brazil, China, and India have little influence on either electricity consumption or economic growth. According to the panel granger causality test, unidirectional causality between GDP and CO₂ was discovered in South Africa, but unidirectionality between CO₂ and GDP was discovered in Brazil. Furthermore, China and India failed to find a link between GDP and CO₂ that was causative. On the other hand, the growth in carbon dioxide (CO₂) emissions in South Africa, Brazil, China, or Russia was unrelated to the consumption of energy. As a result, we can draw the conclusion that the estimates do not yield consistent granger causality results. Accordingly, the authors claimed that uniform policy recommendations cannot be made for the BRICS countries in order to stop environmental degradation.

He et. al (2014) did research between 1983 and 2010 on China's energy use, economic development, and environmental improvement. Functional research criteria were covered by the Johansen cointegration test and Granger Causality test based on VECM approach. The World Development Indicator (WDI), World Bank, National Bureau of Statistics of China, and World Energy Council provided the GDP time series data. The VECM method was used to identify cointegration between the variables. By examining a few carefully chosen statistics, it was found that the EKC theory is disproved in the case of China. Therefore, it was discovered that economic expansion had a unidirectional causal link with energy use and emission, with a bidirectional causation relationship between the two over time. In addition, calculations using the Johansen's cointegrating equation revealed that, while GDP is maintained constant, a 1% increase in energy consumption causes a 1.12% rise in carbon emissions.

Salahuddin & Khan (2013) study of the empirical connection between economic expansion, energy use, and CO₂ emissions in Australia from 1965 to 2007. The functional criteria for the study were covered by the Granger Causality test based on the Vector Auto Regression (VAR) model and the Johansen cointegration test. The time-series data for GDP, energy consumption, and carbon release were obtained from the World Development Indicator (WDI) database. In order to find cointegration among the variables, the VAR technique was used. In Australia, there were no long-term co-integrating relationships between the mentioned variables, such as economic growth, energy consumption, or carbon emissions. As a result, economic growth was found to be causally linked in both directions to energy use and emissions using VAR Granger analysis, but no long-term association between economic growth and carbon emissions was discovered.

Rastegaripour et. al (2019) conducted research on the 1997–2019 period's "link between CO₂ emissions, energy consumption, and economic growth in Iran". The Generalized Method of Moments (GMM) model for Panel Dynamic addressed functional research criteria. The annual panel statistics of Carbon Release, Energy Usage, and Economic Growth were taken from the Statistical Centre of Iran's Energy Balance Sheet and the Central Bank of Iran. The Cobb-Douglas Production function was examined at to see how the selected factors, such as capital and labour, related to one another. The Pedroni, Kao, and Chiang technique was utilized to determine cointegration between the variables. As a result, there were long-term co-integrating connections between the factors that were taken into account, including Iran's economic development, energy consumption, and carbon emissions. A favourable long-term bi-directional causal relationship between energy use and both economic growth and carbon emissions was also shown by the GMM model. Furthermore, the estimates provided by the Two Stage Least Squares equation demonstrated that a 1% increase in energy consumption results in a 0.37% gain in GDP whereas a 1% increase in CO₂ results in a 0.03% reduction.

Mercan & Karakaya (2015) oversee studies on "energy consumption, economic growth, and carbon emissions for a subset of OECD nations from 1970 to 2011 using dynamic panel cointegration analysis". The Cross Sectionally Dependency (CD) with Cross Sectionally Lagrange Multiplier (CDLM) test addressed functional research criteria. Cross-Sectional Augmented Dickey-Fuller was used to analyse the model's stationary behaviour later (CADF).

The World Bank's International Financial Statistics provided the annual panel data on carbon emissions, energy use, and GDP (IFS). Thus, the CDLM approach was utilized to discover cross section reliance among the countries which were examined with cointegration comparison among the variables Gross Domestic Product, energy usage and Carbon release in long-run. Moreover, CADF approach was utilized to discover cross sectional dependency relationships among the series. Later, Cointegration relationship empirical evidence were discovered among the series by using Basher and Westerlund structural break approach. The estimates resulted that the energy usage among OECD countries has a progressive influence on carbon release with a marginal wounding shock on gross domestic growth in long-run.

Nasir & Rehman (2011) used an empirical analysis to examine the environmental Kuznets curve for carbon emissions in Pakistan from 1972 to 2008. Functional research criteria were covered by the Johansen Cointegration Test and Granger Causality Test based on VECM approach. The time-series data for GDP, energy consumption, carbon release, and trade export and import were provided by the World Development Indicator (WDI), Carbon Dioxide Information Analysis Centre (CDIAC), and the World Bank (WB). The VECM method was used to identify cointegration between the variables. As a result, it was discovered over time that the EKC hypothesis was accepted in the case of Pakistan when certain characteristics were taken into consideration. Additionally, VECM Granger causation between economic growth and energy use and emission was discovered to be unidirectional. Additionally, the empirical evidence of the causality test revealed that carbon release has no long-term impact on economic growth, suggesting that Pakistani policymakers can continue to implement growth-oriented measures since carbon emission has no such effect. As a result, carbon emission-related measures can be examined separately. Additionally, short run estimations rejected the EKC hypothesis, corroborating the distinctive literature in the sense that the majority of long run factors affecting emissions are negligible. Due to the negative and statistically significant Error Correction Term (ECT), which showed that the disturbance of the short-run equilibrium would be made up for with a 53% increase in the long-run, the model will also reach equilibrium in less than two years. The Johansen's cointegrating equation calculations also revealed that a 1% increase in trade activity results in a 1.65% rise in carbon emissions. Therefore, it is clear from this study that all of the results are statistically significant and provide long-term support for the use of the EKC model in the Pakistani economy.

Ozturk & Acaravci (2010) conducted research on Turkey's carbon emissions, energy use, and economic growth from 1968 to 2005. The functional criteria of research were once more addressed in this instance by the error-correction based Granger Causality test and the Autoregressive Distributed Lag (henceforth, ARDL) bound test. The labour force statistics were gathered from the Turkish Statistical Institute, and the time series data for carbon emissions were taken from the World Development Indicator (WDI) database (TSI). It was discovered and demonstrated using the linear logarithmic model that EKC is validated in Turkey based on statistically significant evidence of the presence of a long-run relationship between carbon emission and GDP. The ARDL limits test approach was used to find cointegration among the variables in the long run. Additionally, the long-term equilibrium is disturbed by 43% on a yearly basis, which is corroborated by a negative and statistically significant Error Correction Term (ECT). The Granger causality model, however, in the long-run model, indicates that there is no causal relationship between Turkish economy's carbon emissions and its GDP.

Tirgil et. al (2021) over the years of 1961 to 2014, research was conducted on Revisiting the Environmental Kuznets Curve: Evidence from Turkey. WB and WDI provided the annual time-series data for GDP, energy use, and carbon emissions. Sulphur dioxide, particulate matter, and water waste panel data were gathered from the Turkish Statistical Institute (TSI) and the Ministry of Environmental and Urbanization (MEU). The cross-sectionally augmented Dicky-Fuller (CADF) unit-root test to evaluate cross-sectionalism and heterogeneity across panel data and the parametric methodology to investigate the EKC hypothesis covered the experiential criteria of study. The estimates of the FMOLS method, using data from 1961 to 2014, produced an N-type relationship between variables like carbon emissions and economic growth, whereas the Random and Fixed effects models, using data from 1992 to 2013, developed an N-type link between the economic expansion and the indicator of the quality of the wastewater and particulate matter. Additionally, a relationship of the inverted N type between SO₂ and economic development was found for the same time period. They came to the conclusion that the EKC hypothesis was incorrect for the scenario of Turkey utilizing both models.

Table 2. Summary of Literature Review

Authors	Country	Period	Variables	Methodology	Conclusion
"Saboori et al. (2012)"	"Malaysia"	"1980-2009"	GDP, CO2,	ARDL	EKC valid
Mulali et al. (2015)	Latin America & Caribbean Countries	1980-2-10	GDP, REC, CO2,	VECM	EKC valid
"Bilgili et al. (2016)"	17-OECD	1977-2010	GDP, REC, CO2,	FMOLS, DOLS	EKC valid
Murshed et al. (2020)	South Asia	1980-2006	GDP, GHG, LPG, TOP, FDI,	CCMG, AMG	EKC valid
Cheikh et al. (2021)	MENA	1980-2015	GDP, CO2, EC,	PSTR	EKC valid
Ahmad et al. (2017)	Croatia	1992-2011	GDP, CO2,	ARDL, VECM	EKC Valid
Pao et al. (2011)	Brazil	1980-2007	GDP, CO2, EC,	VECM	EKC valid
Baltagi et al. (2019)	81-Countries	1991-2015	GDP, CO2, EI, PD, URB, Trade,	MFVB	EKC valid
Usman & Jahanger (2021)	93-Countries	1990-2016	GDP, EF, TOP, URP, EC, FDI, IQ,	PQR	EKC valid
Liu et al. (2019)	125-Countries	2000-2014	Export diversification, CO2, GDP,	FEM, REM	EKC valid
Akdiri et al. (2021)	BRICS	1995-2018	GDP, EF, CO2, HDI, Coal, Gas, Oil	PMG-ARDL	EKC valid in Long-term
Lopez et al. (2015)	Venezuela	1980-2025	GDP, CO2, REC, EC,	SUR, MAPE	EKC not Valid
He et al. (2014)	China	1983-2010	GDP, EC, CO2,	VECM	EKC not valid

Nasir & Rehman	Pakistan	1972-2008	GDP, EC, CO ₂ , Trade & Export,	VECM	EKC valid in long-term
Magazzino (2014)	6-AESEA	1971-2007	GDP, CO ₂ , EC,	VAR, IRF	Positive relationship among GDP and CO ₂
Pandey & Mishra (2016)	SAARC	1972-2010	GDP, CO ₂ ,	VAR, VECM	EKC valid
Yigit (2021)	D8-Countries	1990-2014	RGDP, CO ₂ , EC,	VAR,	One-way causality found between GDP and CO ₂
Silva et al. (2012)	4 countries	1960-2004	GDP, CO ₂ , REC,	SVAR	Negative relationship among GDP, CO ₂ and REC
Cowan et al. (2014)	BRICS	1990-2010	GDP, CO ₂ , EC,	Panel Causality	Unidirectional relationships among GDP to CO ₂ and CO ₂ & EC found negative relationships
Salahuddin & Khan (2013)	Australia	1965-2007	GDP, CO ₂ , EC,	VAR	Bi-directional relationship among GDP, CO ₂ , and EC
Rastegaripour et al (2019)	Iran	1997-2019	GDP, CO ₂ , EC	GMM	Bi-directional relationship among GDP, CO ₂ , and EC
Mercan & Karakaya (2015)	OECD	1970-2011	GDP, CO ₂ , EC,	CDLM	Positive relationship among EC and CO ₂
Ozturk & Acaravci (2010)	Turkey	1968-2005	GDP, CO ₂ , EC,	ARDL	EKC valid
Tirgil et al. (2021)	Turkey	1961-2014	GDP, CO ₂ , EC,	FMOLS	EKC invalid

2.3.1. An Overview of Literature Review

The latest substantial literature advancement for the Environmental Kuznets Curve has been considered in this chapter for the selected variables. A detailed literature considering the

opted variables provided by different researcher (see Akdiri et al. (2021). As a result, we focused on the literature that considers the validity of the EKC hypothesis in this chapter because these factors have attracted a lot of interest from academics over the past 10 years. With the exception of a few nations like China and Venezuela, the literature that was chosen for this chapter found the EKC hypothesis to be experimentally valid.

2.4. Data and Model

The relationship between CO₂ and financial inclusion has been examined for the BRICS-4 (Brazil, Russia, India, and China) countries as well as the USA for the years 1991 to 2020 in this thesis section. Environmental footprint studies have employed carbon emission (CE) as a dependent variable. Gross Fixed Capital Formation Growth (GFCF) and Gross Domestic Product (GDP) are the independent variables in our model (GFCF). For the BRICS-4 countries and the USA group, Table (1) lists the variables and the sources from which they were derived.

2.4.1. Data Source

The annual panel data, which were collected from 1991 to 2020, were utilized to analyze the data in this thesis. A annual data collection type was used, to prevent the model from being disabled, to preserve consistency, and to produce the proper findings, the data is primarily derived from primary sources. The World Bank's open database is the primary source of all the data. The 2017 data for carbon emissions, real GDP (gross domestic product in US dollars), and GFCG are used.

Table 3. Data Source & Description

Variables	Description	Unit	Form	Source
CE	Carbon Emission (2017)	Percentage	-	World Bank
GDP	Real Gross Domestic Product	Level	Natural Logarithm	World Bank
GFCF	Gross Fixed Capital Formulation	Level	Natural Logarithm	World Bank

Source: (World Bank, 2022).

2.4.2. Corelation Matrix

Correlation matrix defines the degree of correlation between the variables. For our model the correlation matrix is given below.

Table 4. Corelation Matrix

Variables	CE	LnGDP	LnGFCF
CE	1.00	-0.16	-0.05
LnGDP	-0.16	1.00	0.97
LnGFCF	-0.05	0.97	1.00

The table above, shows the coefficient of correlation among the variables under consideration, which has a varies between -1 to +1, with -1 indicates a strongly negative connection and +1 indicates a strongly positive correlation. From the table we can see that carbon emissions shows negative correlation with gross domestic product. On the other hand, it shows positive correlation with gross fixed capital formation.

2.4.3. Descriptive Statistics

Descriptive statistics defines the general statistical information about the individual variables, such as mean, standard deviation, kurtosis, skewness etc.

Table 5. Descriptive Statistics of the Variables

Descriptive Statistics	CE	LnGDP	LnGFCF
Obs.	150	150	150
Max.	1.30	30.69	29.47
Min.	0.12	26.00	24.06
Mean	0.43	28.27	26.85
Std. Dev.	0.25	1.30	1.39
Skewness	0.97	0.32	0.24
Kurtosis	3.62	1.91	1.92
Jarque - Bera	26.36	9.98	8.68
J-B prob.	0.00	0.00	0.00

The table above represents the descriptive statistics of the variables of BRICS-4 countries and USA considered for our model and empirical study later.

The data of all the variables of these BRICS-4 countries and USA has 150 number of observations. The data for gross fixed capital formation, gross domestic product, and carbon emissions are centered over 0.43, 28.27, and 26.85 percent, respectively. The statistic standard deviation which measures the spread or the dispersion of the dataset of CO₂, GDP, and gross fixed capital formation, in relation to its mean is 0.25, 1.30, and 1.39 respectively.

The skewness is a statistic which measures the presence of asymmetry in the distribution of the dataset around its mean. For a normally distributed series, the value of skewness is zero. Therefore, the right/left side of the distribution may have a lengthy tail, according to the positive/negative values of skewness. As a result, the long tail on the right side of the distribution is visible for carbon emissions, gross domestic product, and gross fixed capital formation.

The kurtosis is a statistic which measures the presence of peaked-ness or the flatness of the distribution of the series. For a normally distributed series the value of Kurtosis statistic is 3. Therefore, the estimated Kurtosis values of all the variables shown above indicates the presence of normally distributed peaks.

After estimating that the distribution has skewness as well as peak, it is indicated that the series distribution is normal. The Jarque-Bera probability confirms the presence of normal distribution in all the dataset from 1991 to 2020.

2.4.4. The Econometric Model

The CO₂ emission in any economy is closely associated with either a possible increase in the value of growth or more efficient use of existing Trade and GFCF factors. For BRICS countries and USA, the rate of carbon emission is generally dependent on the share of GDP and GFCF, where almost all the factors are responsible either for reduction or increase in emission (Akalpler & Hove, 2019).

Therefore, this thesis evaluates a model to investigate the impact of investment spendings (GFCF) and real GDP on Carbon emission of BRICS-4 countries and USA. Variables taken in

this thesis are CE which is a dependent variable and independent variables are LnGDP and LnGFCF.

The model of this chapter of the thesis is as follows:

$$CE = f(\text{LnGDP}, \text{LnGFCF}) \quad (2)$$

Following, (Wang et. al, 2011), (Ang, 2007) and (Apergis & Payne, 2009), the main assessment of the econometric model can descriptively be written in the mathematical form as follows:

$$CE_{it} = \alpha_{it} + \alpha_1 GFCF_{it} + \alpha_2 GDP_{it} + \varepsilon_{it}$$

where $i=1, 2, \dots, N$, represents countries taken in the panel, whereas, $t= 1, 2, 3, \dots, T$ represents the time period of the panel. C represents the carbon emission rate, G represents the real GDP, and Y represents the gross fixed capital formation (GFCF). The parameters α_1 , and α_2 represent the long-run elasticities of real GDP and GFCF, respectively. The main task is to estimate these parameters through novel panel data techniques. As expected under the EKC hypothesis, it is postulated that $\alpha_1 > 0$ while $\alpha_2 < 0$.

Thus, we have two hypotheses for this chapter.

Hypothesis 1: GFCF is positively associated to carbon emission in long run for BRICS-4 countries and USA.

Hypothesis 2: GDP is negatively associated to carbon emission in long run for BRICS-4 countries and USA.

Hypothesis 3: GFCF and GDP combined follows the EKC hypothesis.

Considering the approach mentioned in EKC figure discussion of theoretical background, our hypothesis of this chapter focuses on two indicators. The real GDP and the investment spending in the form of Gross Fixed Capital Formation. Since the GDP demonstrates long-term economic indicator and GFCF demonstrates the short-term economic indicator, so, in our framework, real GDP must be negatively related to carbon emissions, and it is investment

spendings that must define the negative relationship with carbon emissions. Hence, together they must follow the EKC hypothesis.

The panel data plots of the three variables taken for our model are shown below.

2.4.5. Panel Data Plot of the Carbon Emissions

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The carbon emissions rate of BRICS-4 countries and USA through the panel data plot from 1991-2020 can be seen below.

From the graph below we can see that the rate of carbon emissions among the group countries of our, is highest for China followed by Russia, USA, India, and Brazil, since the 1991 until 2020. However, due to the increase in GDP level over the years, the China's carbon emissions rate is declining. Interestingly, we can see that in India, the rate of Carbon Emissions neither increased nor decreased significantly since 1991 which is evident from the underperformance of India's economy over the years when compared with the counterpart country China.

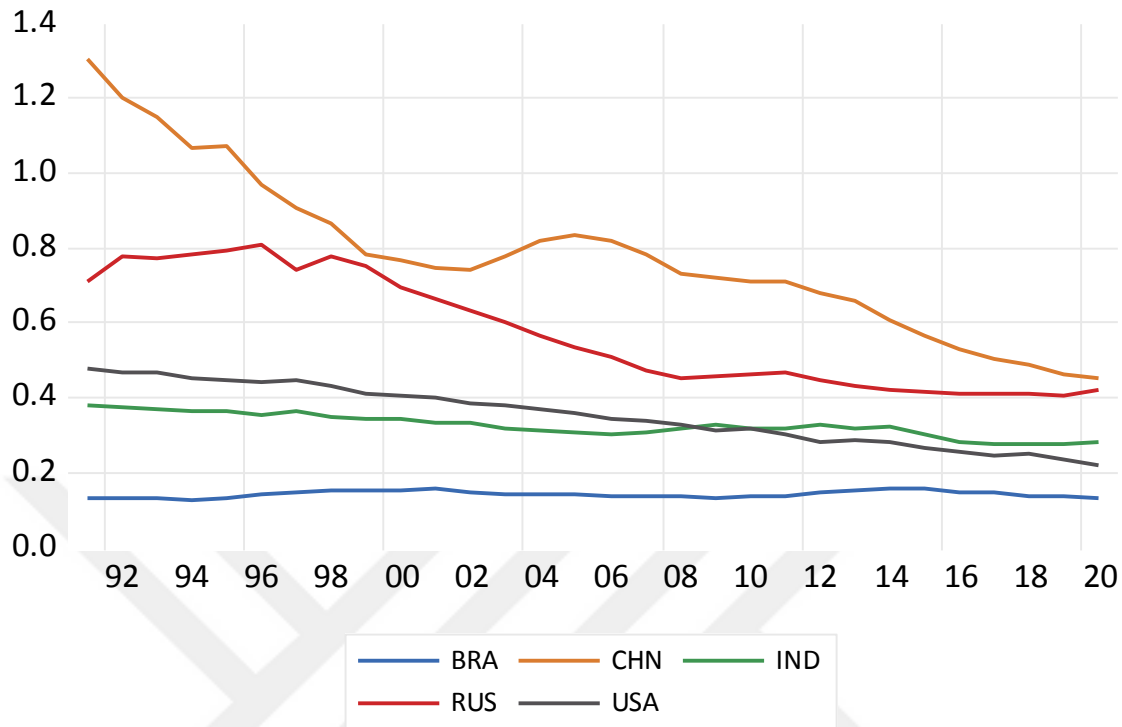


Figure 2. Panel Data Plot of the Carbon Emissions

2.4.6. Panel Data Plot for Gross Domestic Product

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The gross domestic growth rate of BRICS-4 countries and USA through the panel data plot from 1991-2020 can be seen below.

The real GDP of an economy is defined as the "gross domestic product" in constant US dollars. The real GDP is used as our illuminating variable to calculate the effect of total economic growth on the growth rate of carbon emissions since it is the best measure of a country's entire economy. From the year of economic reforms in 1991 through 2020, the World Bank's open data bank website was used to obtain the annual data on real GDP. The chart of GDP shows that the USA is at the top, followed by China. According to the graph below, the Indian economy has also enjoyed tremendous expansion in recent years.

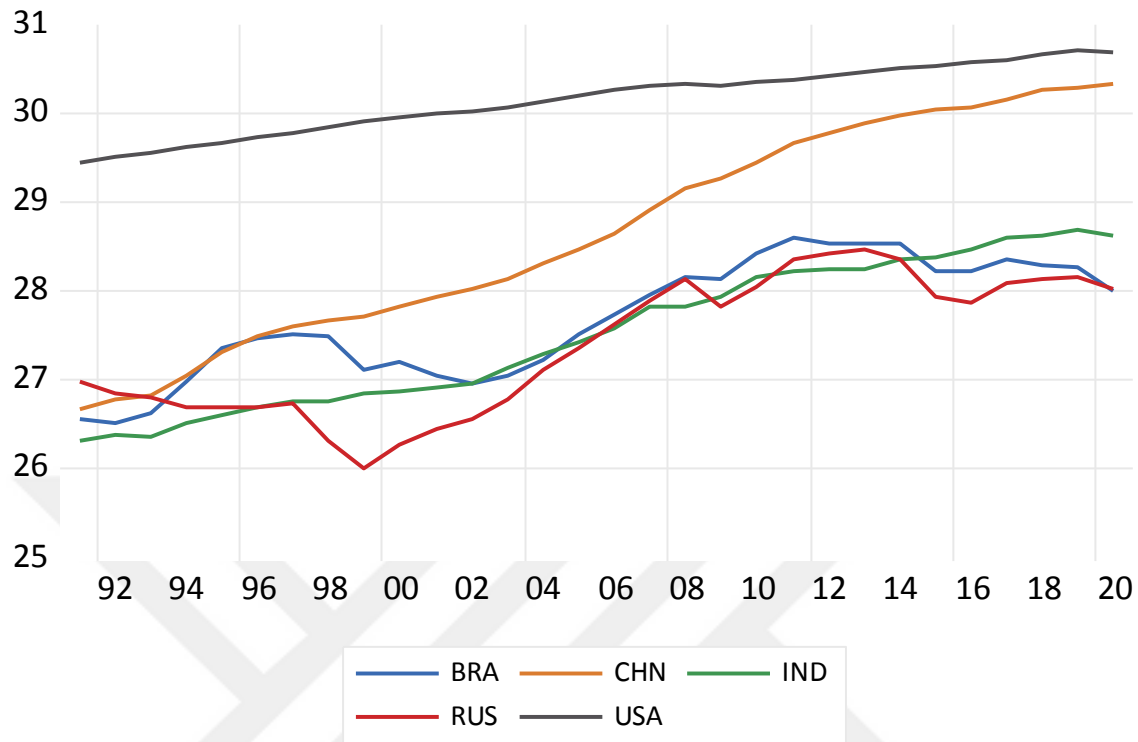


Figure 3. Panel Data Plot for Gross Domestic Product

2.4.7. Panel Data Plot for Gross Fixed Capital Formation

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The Gross Fixed Capital Formation rate of BRICS-4 countries and USA through the panel data plot from 1991-2020 can be seen below.

From the graph below we can see that, in recent past, China is a leading economy when it comes to Gross Fixed Capital Formation; investment spendings. Moreover, the carbon emissions chart also shows that China is a leading carbon emitter, indicating that GFCF plays an imperative role in carbon emissions in these countries.

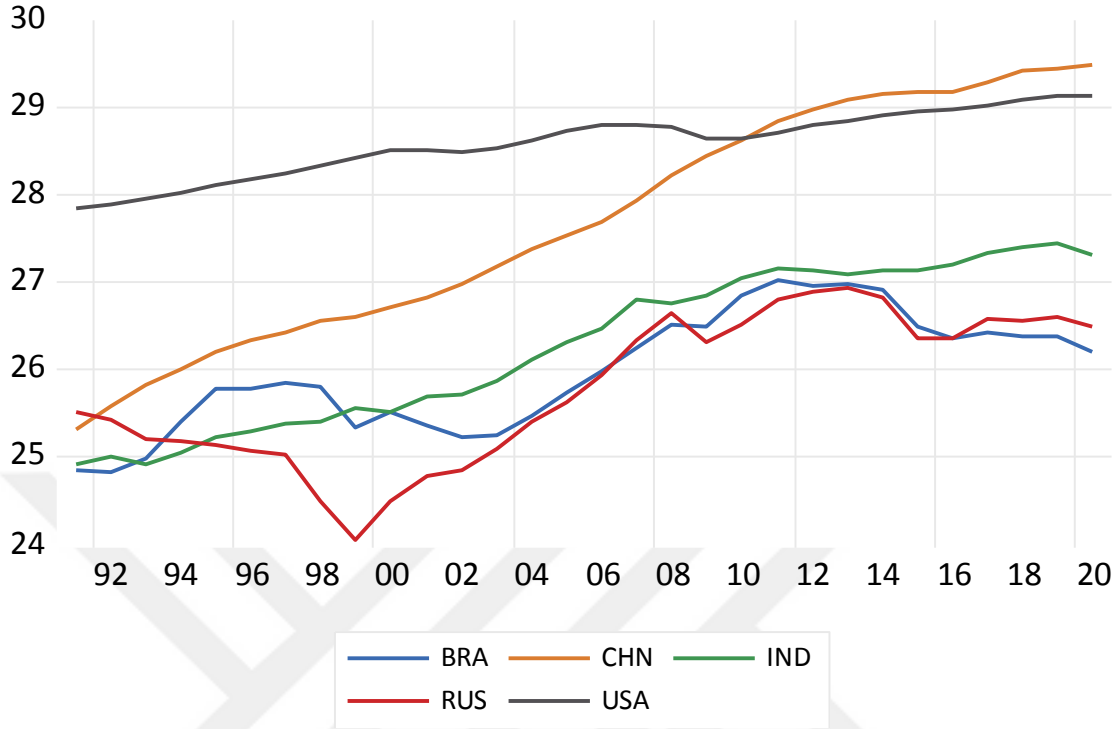


Figure 4. Panel Data Plot for Gross Fixed Capital Formation

2.4.8. Justification for Variables

Carbon emission has been selected as the indicator for environmental degradation due to a significant share in Green House Gas emission. Energy production, heavy industrial pollution, and transportation considered to be the main cause of emission (Le et al. 2020). Main cause of increase in carbon emission rise globally is increase in demand of energy intensity (Wang & Wang, 2020). The econometric model contemplated gross domestic product and gross fixed capital formation since prior empirical research have demonstrated that these variables have a negative impact on carbon emissions. (Radmehr et al., 2021), (Haldar & Sethi, 2021).

2.7. Methodology

A second-generation panel data approach was used in this thesis for Brazil, China, India, Russia, henceforth, BRIC countries. Latest advancement in the econometric techniques has been advancing the research on panel data methods considering cross-section dependency. We have adopted the advanced panel data techniques in these studies described in subsections. Cross-

section dependence test, first and second generations panel unit root test, first and second-generations panel cointegration test, and lastly the innovative dynamic common correlated effects to estimate the coefficients followed by homogeneity test make up the remaining steps of the thesis.

2.7.1. Cross-sectional Dependence Test

In order to define whether cross-sectional dependence (henceforth, CDS) exists in the panel, the thesis has run numerous series of tests, including the CD test and the Lagrange multiple (henceforth, LM) test, the scaled-LM test, and the adjusted scaled-LM test. The LM test homogeneity method as proposed by Breusch and Pagan (Breusch & Pagan, 1980). However, the CDLM1 test produces biased findings when the group mean is zero and the unit mean deviates from zero. CDLM1 can be employed when the panel is considerably larger than the cross-section size (N), while CDLM2 was created by (Pesaran, 2004). The large period (T) and relatively small cross-sections are suitable for this test (N). When the mean pairwise correlation is near to zero, this test will not be effective (Pesaran, 2004). By including both the variance and mean to the test statistics, (Pesaran et al. 2008) created a bias-adjusted test of cross-sectional dependence (LMadj) to address this flaw. The bias-adjusted LM test is presented below in a step-by-step format.

$$LM_{LM1} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \quad (3)$$

The sample estimate of the pairwise correlation coefficient ($\widehat{P}_{ij}^2$) is shown in equation (1). The LM test was also proposed in a scaled-down form by (Pesaran, 2004).

$$Scaled\ LM\ Test = \sqrt{\left(\frac{1}{N(N-1)}\right)} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \widehat{P}_{ij}^2 - 1) \right] \quad (4)$$

In the case of $N > T$ the scaled LM test shows severe size misrepresentations (Pesaran, 2004). (Pesaran, 2004). Therefore, (Pesaran, 2004) As a result, (Pesaran, 2004) created an alternate CD test that is applicable for either $N > T$ or $T < N$.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \right] \quad (5)$$

When Both $N \rightarrow \infty$ and $T \rightarrow \infty$, "The scaled mean of the pairwise correlation coefficient", rather than the square of the pairwise correlation coefficient used in the LM test of CSD, is the basis for the CD test, which monitors an asymptotic normal distribution. The CD test assumes reliable estimates of the heterogeneous dynamic panel data and comprises of several breaks in slope coefficients. By including the precise variance and mean of the LM statistics, (Baltagi et al. 2012) modified the CD test procedure.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \frac{(T-k)\widehat{P}_{ij}^2 - \mu_{Tij}}{\sqrt{v_{Tij}^2}} \quad (6)$$

In the above equation v_{Tij}^2 and μ_{Tij} represents the rigorous discrepancy of standard deviation and mean of $(T-k)\widehat{P}_{ij}^2$ which was categorized by the research (Baltagi et al. 2012). Table LMadj the portion of this thesis titled "Test Results" offers cross-sectional dependence findings for the variables and cointegration equations employed in CD_{adj} test. Different test (CD, scaled LM, LM-adjusted) are used to check the cross-sectional difference between units (CDS). The results of these CDS tests are valuable in determining the best estimation methodology.

In a panel data analysis, the cross-sectional dependency test in the series is a crucial step. If a researcher does not take into account the CD in the series, the results of the investigations could be deceptive and erroneous. (Dogan et al., 2017). By using a bias-corrected scaled LM (Lagrange Multiplier) test analysis created by Baltagi et al., this particular problem was handled in this work (2012). The following are examples of the Bias-corrected scaled LM test.:

$$Bias - corrected Scaled LM = \sqrt{\left(\frac{1}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T_{ij}\widehat{P}_{ij}^2 - 1) - \frac{N}{2(T-1)} \quad (7)$$

In the calculation above (4), N represent the number of cross-sections, T represent the time dimension. Additionally, $\widehat{p}_{ij}$ reflects the residuals' pair-wise correlation coefficient. The usual normal distribution for the aforementioned CD test is asymptotic. The alternative hypothesis of cross-section dependency is tested in this study against the null of no cross-section dependency. (Baltagi et al., 2012). Therefore, the second-generation panel unit root test must be employed if the cross-section dependency is discovered in the series.

2.7.2. IPS Panel Unit Root Test

Two forms of analysis, known as First-generation and Second-generation panel unit root tests analysis, are included in the literature on linear panel unit root tests. In order to test the CD in the panel, first-generation were introduced, but they did not have complete control over the CD in the panel. We are employing the IPS (Im-Pesaran-Shin) test created by Im et al. (2003) for first-generation panel unit root tests. Previously, the autoregressive coefficient assumption of homogeneity was criticized in panel unit root tests. The average of the Augmented Dickey-fuller (ADF) test's statistics (t) must be taken in order to obtain the IPS panel unit root test statistics.:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^N t_{pi} \quad (8)$$

where, t_{pi} represents the individuals t -statistics. According to the IPS test null hypothesis, each series in the panel has a unit root. (Im et al., 2003; Baltagi, 2008).

2.7.3. CIPS Panel Unit Root Test

The CIPS test of second-generation panel unit roots (henceforth, Cross-sectionally Augmented IPS). Additionally, it uses the cross-sectionally augmented Dickey-Fuller (henceforth, CADF) test proposed by "Pesaran (2007)" to examine variable stationarity. Specifically, the test estimates CADF test statistics for each unit of the panel before acquiring the cross-sectionally augmented Im-Pesaran-Shin (henceforth, CIPS) test, which uses the typical value, or the arithmetic mean, for the entire panel with CADF estimates. Due to the unobserved common component identified by the test, cross-section dependence develops. Therefore, this test validates in both conditions for both " $N > T$ and $T < N$ " (Guloglu and Ivrendi, 2008). The mean of the CADF test estimates refers to the CIPS test which is as follows:

$$CADF = t(N, T) = \frac{\Delta y_i^t \bar{M}_i y_{i-1}}{(\Delta y_{i-1}^t \bar{M}_i y_{i-1})^{1/2}} \quad (9)$$

which is transformed into CIPS by averaging it as described below.

$$CIPS = N^{-1} \sum_{i=1}^n t(N, T) \quad (10)$$

Using Monte Carlo simulation, the related test estimates are related to the crucial table estimation values in "(Pesaran, 2007)". When estimated CIPS values exceed the critical table values, a variable is regarded as panel stationary (Katircioglu et al. 2015). The "alternative hypothesis" stated that at least one individual is stationary and the estimated values of the CIPS in this study are greater than the critical values, which verified the stationarity of the panel in this section of the thesis. The "null hypothesis" of this test states that all the individuals within a panel data have a unit root (Estimates part). The estimates section of the study demonstrates the cross-sectional dependence and second-generation stationarity of each variable. In order to do this, we adhere to the first and second generation cointegration tests provided by Pedroni (1999) and Westerlund (2007) respectively.

2.7.4. Panel Cointegration Test

The variables CO₂, GDP, and GFCF were tested for cointegration using the Pedroni (1999) and Westerlund (2007) ECM panel cointegration tests. The alternative hypothesis is that there is cointegration among the panel, while the null hypothesis is that there is no cointegration. There are several tests to check cointegrations in the long run, such as (Kao,1999), (Pedroni, 1999), (Pedroni, 2004), and (Maddala & Wu, 1999). Due to the first-generation co-integration tests' deceptive results, which overlook several crucial problems including heteroskedasticity, CDS, and serial correlation (Xue et al. 2021). In order to determine whether there is a long-run convergence among the variables, we performed a panel cointegration test of the first and second generations in this work. First, we used Padroni's (2004) first-generation test, and then Westerlund's (2007) second-generation cointegration test (Westerlund, 2007) test is more accurate because it accounts for all of the aforementioned problems, including serial correlation, heteroskedasticity, and CDS. This test permits co-integration or long-run associations between variables, and it permits accurate interpretation of results in the presence of small data or structural discontinuities. (Westerlund, 2007). This test used panel-based statistics (panel Γ and panel α) and group mean-based statistics (panel Γ and panel α). While group mean-based statistics regress the weighted mean for the error-correction term, panel-based statistics calculate the error-correction term for the entire panel. Therefore, using error correction for both the entire

panel and specific cross-sections, these test statistics analyze the long-term link among associations among the selected variables.

2.7.5. First Generation Cointegration Test of Pedroni (1999)

This study first used the first-generation panel cointegration test matured by Pedroni (2004), to examine the existence of relationships among the panel. The seven various statistics known as the "within and between dimensions" are examined in this test. The alternate hypothesis looks at the cointegration that isn't present in the panel whereas the null hypothesis looks at the cointegration that is. The Pedroni, (2004) cointegration test statistics are indicated by the following equation:

$$Y_{it} = \alpha_{it} + \delta_i t + \gamma_{2i} E_{it} + \gamma_{2i} L_{it} + \gamma_{3i} K_{it} + \varepsilon_{it} \quad (11)$$

In the above given equation, $i=1,.. N$ for individual countries in the panel and $t=1,..T$, indicates the time period. The factors α_{it} and δ_i permit the possibility of country-specific fixed effects and determined trends, respectively. ε_{it} denote the deviations in the residual estimates in long-run relationships. All variables are demonstrated in natural logarithms, the γ_s indicates the elasticity of the model. To test the "null hypothesis" that there is no cointegration in the heterogeneous panel, (Pedroni, 1999 & 2004) offered a variety of statistics based on the residual of (Engel & Granger, 1987) cointegration regression.

2.7.6. Second Generation Cointegration Test of Westerlund (2007)

This error-correction model of panel second generation cointegration test is matured by Westerlund (2007), which is used to examine the null hypothesis of no cointegration. This test is used to determine whether the error-correction term for a conditional panel correction model is equal to zero. This test examines if a group mean has an error correction (G_τ and G_a) and for panel (P_τ and P_a). We used the (Westerlund, 2007) model for error correction to categorize the existence of cointegration among the panel and analyze the presence of error correction in the heterogeneous panel model. Following equation represents the Westerlund (2007) are as follows:

$$\Delta CO_{2,it} = \alpha_i^C + \lambda_i^C (CO_{2,it-1} - \beta_i^C GDP_{2,it-1} - \gamma_i^C GFCF_{i,t-1}) + \sum_{j=1}^m \theta_{i,j}^G \Delta CO_{2,it-j} + \sum_{j=1}^n \delta_{i,j}^G \Delta GDP_{it-j} + \sum_{j=1}^p \phi_{i,j}^G \Delta GFCF_{i,t-j} + \mu_{i,t} \quad (12)$$

2.7.7. Slope Heterogeneity Test

This test is designed to determine whether slope heterogeneity exists in the model and to determine which estimated model is the best choice. Therefore, the homogeneous slopes test, which was proposed by (Pesaran & Yamagata, 2008). Model of homogeneity test approach based on Swamy (1970), which estimates the $(\hat{\Delta})$ delta and to adjusted delta $(\hat{\Delta}_{ad})$ to analyze the null theory of homogeneity, $H_0: \lambda_i = \lambda_j$ in favor of economic homogeneity and opposed to the opposite argument for economics that tends toward heterogeneity, $H_1: \lambda_i \neq \lambda_j$ based on the supposition that there is a non-zero proportion between each pair of variables that can be located anywhere for $i \neq j$. A test Statistics are as follows:

$$\hat{\Delta} = \sqrt{N} \left(N^{-1} \hat{H} - \frac{1}{2l} \right) \sim X^2_l \quad (H)$$

$$\hat{\Delta}_{ad} = \sqrt{N} \left(N^{-1} \hat{H} - \frac{l}{SE(T, l)} \right) \sim N(0, 1) \quad (SE)$$

In the above-mentioned equation, N represents the "number of cross-sections, l indicates the number of independent variables, H denotes the heterogeneous test statistic, and $SE(T, l)$ is the demonstration of the errors in a standardized form. A larger sized sample (whole data set) is estimated through Eq. (H), whereas small sample-sized samples (ER sample, CR sample, and WR sample) are estimated in the Eq (SE)".

2.7.8. Dynamic Common Correlated Effects (DCCE) Estimation Test

The "Dynamic Common Correlated Effects" (henceforth, DCCE) methodology, which was recently created by Chudik and Pesaran (2015), was used in this study to elaborate on the CD issue that was not addressed in prior models that provide biased estimates. Previous research asserted that the development era's economic forces and unknown shocks led to the emergence of CD. This method's key justification was that it forecasts the variables as common components and attributes the CD to unnamed and unseen sources. which were mostly based on the mean

group (MG) estimation, pooled mean group (PMG) estimation, and common correlated effects (CCE), which were developed for the first time by (Pesaran & Smith, 1995 & 2006) respectively. The main drawbacks of this recently developed methodology are that it is appropriate for dynamic panels and considers the drawbacks of the CCE methodology. In addition to the foregoing comments, (Ditzen, 2018) expanded the DCCE approach of (Chudik & Pesaran, 2015) for the heterogeneous panel estimating outcomes for both short- and long-term estimations. As a result, it was inevitable that the DCCE approach would address a number of critical issues, many of which were either disregarded or went undetected in the previous methodologies, as was evident from the results of many studies. These include I including the CD problem and empirically resolving the issue by integrating the average values of cross-sectional units and the lags in the analysis, (i) It addresses the issue of heterogeneity; (ii) By using common variables, the model incorporates the dynamic common correlated effects; (iii) It addresses the problem of heterogeneity; (iv) The major consideration may be taken into account when it is appropriate for the situation of sample size; and (v) The main justification or introduction for this particular model was that it produces accurate estimates in the case of unbalanced data and structural breaks. 2016 (Ditzen).

The principal goal of this model was to identify the causes of variables on each other in BRICS-4 countries and USA for carbon emission by using carbon emission as a dependent variable and GDP and GFCF as our independent variables. The model's specifications were elaborated in a pragmatic manner that was appropriate.

In order to comply with the model specifications, the DCCE equation stated below can be written.:

$$Y_{it} = a_i Y_{it-1} + \delta_i X_{it} + \sum_{P=0}^{PT} \gamma_{xip} \overline{X_{t-P}} + \sum_{P=0}^{PT} \gamma_{yip} \overline{Y_{t-P}} + \mu_{it} \quad (13)$$

In the equation above, "the dependent variable and its lag are both present. Y_{it} represent as dependent variable while its lag is denoted by Y_{it-1} , and X_{it} represents the independent variable, subscripts I and t show cross-sectional and time dimensions". "The common unobserved factors are expressed by γ_{xip} and γ_{yip} and PT and μ_{it} shows the lag of cross-sectional averages and the error term". By adding the ecological footprint as a dependent

variable, we have significantly expanded our variables for the Carbon emission (Pollution heaven BRICS-4 countries) hypothesis (Carbon emission).

$$YCO_{2,it} = a_i CO_{2,it-1} + \delta_i X_{it} + \sum_{p=0}^{p^T} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{p^T} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (14)$$

The above equation, $a_i CO_{2,it-1}$ is the log of ecological footprint (carbon emission) used as the dependent variables, $\delta_i X_{it}$ indicates the set of independent variables log like LnGDP, and LnGFCF are reported by the X_{it} .

2.8. Empirical Estimates

In this subdivision, the study details the empirical findings obtained and discusses the results. We begin with conducting, first, the cross-section dependent test to confirm cross-sectional dependency, second, panel unit root tests to check stationarity at first difference, third, long run cointegration test to check the presence of long run association between the taken variables. Fourth, we estimate the coefficients by employing the novel "Dynamic Common Correlated Effects:" Mean Group and Pooled methods. Finally, fifth, we test for heterogeneity of the slope coefficients, using the slope homogeneity test. Hence, the estimates of each test mentioned above are as follows.

2.8.1. Cross Section Dependence Test

Initially, study conducts the CD tests among the series to examine the cross-sectional dependency and indicate which unit root must be conducted. The study considered the outcome of the empirical findings of the bias-corrected scaled LM test. Moreover, the thesis includes the findings of Pesaran- CD, and Pesaran scaled LM tests.

Table 6. Cross Section Dependence Test

Variable	Pesaran-CD		Pesaran-scaled LM		Bias-corrected scaled LM	
	Stat.	p-value	Stat.	p-value	Stat.	p-value
CE	7.69	0.00*	31.98	0.00*	31.90	0.00*
LnGDP	15.75	0.00*	53.47	0.00*	53.38	0.00*
LnGFCF	14.78	0.00*	47.20	0.00*	47.12	0.00*
					Breusch-Pagan LM	
Model	1.76	0.05**	26.36	0.00*	127.89	0.00*

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively.

As shown in Table above, all the probabilities regarding individual variables and the model equations are smaller than 0.01, which is a statistically significant measure. Hence, the findings of the tests given sufficient evidence to reject the null hypothesis no cross-sectional dependency across the BRICS-4 countries and USA leading to accept the presence of CD among the individual cross-sectional units, the null hypothesis is strongly rejected at the convenient level of significance. Depending on the empirical outcomes of the cross-section dependency examined in the series, in next section of the study, we conduct a second-generation panel unit-root test named as CIPS and CADF along with first generation IPS test to advance the findings of the study.

2.8.2. Panel Unit Root Tests

The past studies of (Hadri, 2000), (Levin et al., 2002), (Im et al., 2003) and (Breitung, 2005) first-generation panel unit root tests simulate a cross-section independency which indicates each unit is relatively affected by all possible shocks. In addition, second-generation panel unit root further predicts that each unit may not be analogously affected by economic

shocks (Taylor & Sarno, 1998; Breuer et al, 2002; Pesaran, 2007; Hadri & Kurozumi, 2012;). Hence CIPS and CADF tests are employed in this thesis chapter.

Table 7. IPS, CIPS, and CADF Unit Roots Tests

Variables	IPS		CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
CE	-1.12	-4.87*	-2.19	-4.54*	-1.63	-2.69*
LnGDP	-1.53	-3.17*	-2.04	-3.77*	-2.14	-2.76*
LnGFCF	-1.58	-3.27*	-2.18	-3.66*	-1.77	-3.06*

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively.

As noted in the Table of unit root, the values of IPS, CIPS, and CADF test statistics for all the variables are less than the critical table values. However, all other test statistics showing non-stationarity of the variables at level, indicating that all the variables are found to be stationary at first difference with 1% statistical significance. Since, our variables are differenced stationary, therefore, we can test for long run cointegration among them because stationary form of no-stationary series may be determined using cointegration analyses (Tari, 2010).

2.8.3. Panel Cointegration Test

In our thesis, I have employed two cointegration tests, namely, Pedroni (1999) residual cointegration test and Westerlund (2007) cointegration test to form the existence of long run association between carbon emission, real gross domestic product, and gross fixed capital formation for BRICS-4 countries and USA between 1991-2020 time-period.

2.8.4. Pedroni (1999) Residual Cointegration Tests

Pedroni cointegration test which is a first generation cointegration test since it does not consider the cross-sectional dependency in the data. This test is used to check and verify the presence of long run association between the variables of our empirical model. The estimates of this test as shown below confirms the presence of long run association between the variables.

Table 8. Pedroni (1999) Residual Cointegration Tests

HO: no cointegration	Value	p-value
Modified Philips-Perron t	2.08	0.01*
Philips-Perron t	2.02	0.02**
Augmented Dickey-Fuller	2.05	0.02**

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively.

From the table above, we can see that all the t-stats are statistically significant like, Modified Philips-Perron t-stat, Augmented Dickey-Fuller t-stat, and Philips-Perron t at 5% respectively. These p-values of Pedroni (1999) t-stats indicates that there exist a long run cointegration between the variables such as Carbon Emission, Gross Domestic Product and Gross fixed Capital Formation of BRICS-4 countries and USA between the 1991-2020 time-period.

2.8.5. Westerlund (2007) ECM Panel Cointegration Test

Fundamentally, first generation cointegration tests are commonly used for econometric models, but estimates can be biased on the existence of cross-sectional dependence (Johansen, 1988; Kao, 1999; Pedroni, 1999). Due to this reason, the second-generation panel cointegration tests is performed that allow for cross-sectional dependence for all the variables of the considered model (Westerlund & Edgerton, 2007).

Table 9. "Westerlund (2007) ECM Panel Cointegration Test Results"

HO: no cointegration	Value	Z-value	P-value
Gt	-2.42	-2.23	0.01*
Ga	-8.85	-1.23	0.00*
Pt	-5.23	-2.36	0.00*
Pa	-10.02	-3.43	0.00*

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively.

Also, the Westerlund (2007) second generation cointegration test indicates the presence of long-run cointegration between the considered variables that is, CE, LnGDP, and LnGFCF. The p-values of Gt, Ga, Pt, and Pa statistics are less than 1% which implies there is statistically significant long-run cointegration between the variables such as Carbon Emission, Gross Domestic Product and Gross fixed Capital Formation of BRICS-4 countries and USA between the 1991-2020 time-period.

2.8.6. Slope Heterogeneity Test Results

To check if the slope coefficients of our model are heterogenous, we applied slope homogeneity test. The null hypothesis is that the slope coefficients are homogenous. Also, the null hypothesis for the underlying test indicated that the slope of the cointegration equations does not differ among cross-sections of the panel (Pesaran & Yamagata, 2008).

Table 10. Slope Heterogeneity Test Results

H0: slope coefficients are homogenous	Delta	p-value
	20.78	0.00
Adj.	20.32	0.00

The null hypothesis to be tested is the existence of slope homogeneity, which is rejected for our model. Thus, as shown in the table above, all the probabilities are statistically significant at 1% which is indicating that the country specific constant terms and slopes are heterogenous and therefore we adopt the novel Dynamic Common Correlated Effects to estimate our coefficients since it allows for heterogenous slope coefficients. The findings of our test are consistent with (Chaudhry et al, 2022).

2.8.7. Dynamic Common Correlated Effects Estimates

The novel Dynamic Common Correlated Effects estimated results of our econometric model for overall BRICS-4 countries and USA, are presented in the table down below. The value of lags for the dependent variables (CE,) in this thesis research models is associated significantly with their explanatory variables (LnGFCF, and LnGDP). Taking into consideration of diagnostic issues of the model, the "Cross-Sectional dependency test" confirms that the series experience "cross-sectional dependence". In coming paragraph based on the empirical findings of the DCCE model are as shown below.

Table 11. DCCE- Pooled Mean Group & Mean Group Estimates

	Pooled Mean Group		Mean Group	
	Coef.	p-value	Coef.	p-value
D.CE				
L.CE	-0.30	0.00	-0.31	0.00
LnGDP	-0.10	0.10***	-0.13	0.00
LnGFCF	0.08	0.10***	0.06	0.03**
_cons	-2.81	1.00	0.50	0.50

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively

Mean Group Variables: L.CE, LnGDP, LnGFCF

Cross Sectional Averaged Variables: D.CE, L.CE, LnGDP, LnGFCF

Empirical finding of the research using DCCE model, where both PMG and MG statistics indicate that the economic growth i.e., LnGDP has the negative and statistically significant relationship with carbon emission of BRICS-4 countries and USA between the years 1991 to 2020. Therefore, it has given the indication that the economic growth and carbon emission both are negatively related with each other, which indicates that the increase in GDP will decrease the CE in BRIC countries. The empirical findings accept, first hypothesis of this chapter, and "the results of the research are aligned with", (Dogan et al, 2017) where their findings suggested that the increase in GDP is reducing carbon emission in OECD countries and (Saint et al, 2019) where it was also found that Carbon Emission and GDP are inversely related to each other. Additionally, "these findings are also supported" by (Yalcinkaya et al, 2017).

Conversely, we have found that the LnGFCF (also called investment) is showing "statistically significant positive relationship with carbon emission" indicating that with increase in gross fixed capital formation, carbon emission has also been rising. "These findings are consistent" with the (Bekhet et. al, 2017) where GFCF was found to be positively related with carbon emission and the accepts, second hypothesis of this chapter. Additionally, the empirical findings of (Khan et al, 2020) also supports our estimates since their results indicate that GFCF is positively related to Carbon emission. Thus, acceptance of the first two hypotheses leads to accepts the third hypothesis which validates the EKC hypothesis in BRICS-4 countries and USA.

2.9. Conclusion

This thesis research investigates the relationship between carbon emission as dependent variable with gross domestic product and gross fixed capital formation as independent variable in the BRICS (excluding South Africa) countries and USA between 1991-2020 time-period by adopting a novel approach known as the Dynamic Common Correlated Effect (DCCE) model to check EKC hypothesis. Since all the variables showed cross-sectional dependence, therefore along with the IPS unit roots test, both "CIPS and CADF unit roots test showed that all the variables are differenced stationary". Also, both the "Pedroni (1999) and the Westerlund (2007)" tests showed that all the variables, i.e., "carbon emission, gross domestic product and gross fixed capital formation" are cointegrated in the long run. Moreover, "the slope homogeneity test

indicated that the country specific slope coefficients are heterogenous". Thus, "DCCE method was adopted to estimate the long run coefficients". The estimates of the "DCCE method indicates that carbon emission and gross domestic product are negatively related, whereas the gross fixed capital formation is positively related with carbon emission which indicates the acceptance of the EKC hypothesis in BRICS-4 countries and USA".



3. THE EPC HYPOTHESIS REVISITED IN G-20 COUNTRIES: A NOVEL PANEL DATA ANALYSIS

3.1. Introduction

The risk and uncertainties of GHG emission interconnected to climate change which can affect global economic system (Lennan & Morgera, 2022). The changing condition in climate change is mainly due to Greenhouse gas emission (henceforth; GHG), which is interconnected to the consumption of fossil fuel (Dogan, 2016). Moreover, rising problem of unemployment is causing more GHG. The drastic changes in the climate conditions are one of the most concerning problems of the 21st century due to the shifting balanced in environmental conditions. Every year GHG emission of the world is 50 billion tones each year which is 40% higher than emission in 1990 (WB, 2020). In total the amount of GHG emission released by G20 countries each year is 80% of the total GHG emission of the world, where 60% of the world population lives in G20 countries (WB, 2020). Therefore, REC and Oil Rent (henceforth, OR), can mitigate the growing problem of GHG, and OR (Usman et al., 2022 & Khobai, 2020). Hidden development in Energy-Economy-Environment economy Model (E3ME) literature can help in the reduction of GHG emission in long term for the developing economies (Sgouridis et al., 2022). Thus, due to the shortage in the literature and criteria of validation of the E3 model this study is avoided the consideration of the model. Although, individual economies empirically found the advantage of using E3ME but the gap in long-run has yet to be filled (Gramkow & Anger-Kraavi, 2019, Zang et al., 2019, Bloss & Eickhout, 2021, Fatih et al., 2021).

The issue of global warming, climate change and its impact on socio-economic structure of the world were brought into consideration by United Nations, Rio Summit in 1992. Later, in 1997 the Kyoto Protocol is signed by the particularly by developing nations to mitigate the rising problem of GHG. Thus, in 2015 an agreement named as Paris Agreement was signed to combat the rising temperature mainly to combat the problem of global warming (Bhattacharyya, 2019).

The strategic goal of Group of twenty (G-20) countries is to protect the future of global economic growth and prosperity so that the increasing problem of Green House Gas emission can be tackled without affecting the economic growth and create a sustainable world. The efforts

of all nations are focused and concerned about the multiple challenges of encouraging economic growth and coping climate changes. Growing economies and development is considered to be the main cause of GHE. World's two-third population and land are under G20 countries, which is in total 82% of GDP of the world. The G20 countries are more concerned to use and advanced in the development and REC based technologies domestically and globally.

This study aims to investigate the nexus between GHG, UNP, REC, and OR among G20 countries for the period of 1991-2021 to check the Environmental Philips Curve (henceforth, EPC). The other factor which might be useful for this study did not consider due to the unavailability of data for some countries. The main limitation of the study, which considered can be the unavailability of data. Thus, this study will analyze the selected variables to see the long run association among the variables. part of the research delivers an outline for Global Greenhouse Gas Emission (kt of CO₂ equivalent) for G-20 countries based on World bank emission data set. The percentage of GHG as CO₂ is 76%, CH₄ is 16%, N₂O is 6%, and F gases is around 2% (EPA, 2020).

The economic activities of the world are also depending on the sectors. Where Electricity and Heat Production is 25%, Agriculture, Forest and Other Land Use is 24%, Industry is 21%, Transportation is 14%, and Other Energy is 10% (EPA, 2020)

3.2. Theoretical Framework & Background

This section of the study will elaborate on the theoretical background to analyze the nexus between three environmental indicator GHG, REC, OR with UNP as variables. This study emphasized effort on the justification of novel idea of "Environmental Philips Curve" in the case of G20 Countries by considering the environment and unemployment rate.

Theoretically can be describe and suggests a two-channel theory "Growth Channel" and "Preference Channel". Where in growth theory unemployment decreases the growth and mitigate the energy consumption. Therefore, Carbon emission rate is expected to decrease. Another channel preference indicates that unemployment lessens the income of the individual, which leads to restricts the individual/households according to the preferences of consuming environment friendly goods, which directly in favor of environmental quality improvement.

3.2.1. The "Environmental Philips Curve"

By thoroughly evaluating the environmental contamination curve, the relationship between unemployment and environmental pollution is studied. A. W. Philips created the Philips Curve idea in 1958 to denote the conventional relationship between unemployment and environment. EPC asserts that it is the inverted function that holds that unemployment and pollution are inversely related. The Philips curve's foundation was labor input costs associated with production, but since that pollution and income are strongly correlated, that foundation has been no longer in effect. (Shahbaz et al. 2016; Saidi & Hammami, 2015). Therefore, higher economic growth rates are linked to higher levels of GHG, unemployment, and output and income, respectively. According to Okun's law, as production declines in a positive way, unemployment and production in an economy are positively correlated (Okun, 1962). Thus, increases in income thereby support the GDP while reducing pollution and employment rates. As a result, it was noted and verified that at a particular technological stage, unemployment and pollution had a negative relationship. The Philips Curve's nexus with the environment was performed and noted on the basis of this (henceforth: EPC). The tenacity of this study is to test the theory by combining GHG emissions from oil rent and use of renewable energy sources.

3.2.2. "Renewable Energy Consumption and Ecological Footprint"

In an economy energy considered as the most significant factor that enhance the economic growth from time when natural resource considered as mainstream for the production (Reilly, 2012). Consumption of fossil energy drastically impacting the climate conditions due to level of emission discharge. The high demand of energy in heavy industries sector and other economic activities for development is impacting positively in both short and long-run (Ozcan & Ozturk, 2019). Although, the role of (SDG-7) that is, Sustainable Development "Goal-7 (affordable and clean energy) and SDG13 (Climate action)" is the motivation for the shift concerning renewable energy consumption. SDG is Vision for 2030 adopted in 2015 by United Nation to transform the world (UN, 2015; Oerther et al., 2020). Therefore, Renewable energy consumption and GHG are correlated to each other in positive way, indicating that it is reducing the environmental degradation, where consumption of renewable energy is positively improving the economic

growth in short but proper policy implication and planning are necessary to have some improvement in "GHG emission in long run" (Mohsin et al, 2021).

Additionally, the advantage of REC has gained widespread acceptance since non-renewable energy consumption increases emissions. The use of renewable energy sources has thus been the focus of think tanks to ensure sustainable environmental quality. By taking the place of fossil fuel, renewable energy sources aid in the restoration of the ecosystem. REC is found to mitigate the GHG emissions and counteracting the rise in global warming (Wang et al, 2018; Owusu & Asumadu-Sarkodie, 2016; Edenhofer et al, 2011). In light of this, it can be said that using RECs helps reduce pollution as compared to burning fossil fuels. Hence, the suitable infra-structure and technology is the basic requirement for REC implication to combat the greenhouse gas emission as ecological footprint.

3.2.3. Unemployment vs Ecological Footprint

It is stated in the literature that the impact of unemployment on ecological footprint has a significant impact. Its impact varies on the level of the unemployment, by generating the unemployment decreases the level of growth rate which is directly connected to the consumption and production theory. Although the sectoral change in the labor decrease the level of emission, China and India is the largest labor population force where seasonal and sectoral labor force migration could be considered the lowest level of emission in India but same is not valid in case of China due to its export policies (Castellanos & Heutel, 2019; Kriegler et al, 2014). Therefore, to reduce an economy's ecological footprint, short-, medium-, and long-term effects are taken into account, such as switching from carbon-intensive to low-carbon sector by eliminating jobs and industries and creating new ones. (Frankhaeser et al, 2008).

The high employment rate needs more energy employment which further cause the emission, Thus, in an economy the consumption of REC energy and technological innovation and policy implication are necessary to tackle the ecological footprint and growing problem of unemployment by creating green industries (Adesina et al, 2019; Khan et al, 2020; Saboori et al, 2022). Thus, it can be withdrawn into the argument that an increase in unemployment level

does not always decrease the ecological footprint. Moreover, the negative impact in renewables can lead to the long-term growth in unemployment.

3.2.4. Oil rent vs Greenhouse Gas Emission

The literature in the context of resources rent is still growing, as well as oil rent. Those economy which are based on oil their primary source of income are oil export, consumption, and production. From the pumping and using fossil fuel energy for economic growth they consume and discharge GHG emission on a large scale (Chygryn et al, 2020). The environmental condition in those countries seemingly worsening day by day due to the rise in temperature, water scarcity, air pollution, soil erosion and many more which yet did not noticed. Especially in Middle Eastern countries (henceforth; MENA) the climate conditions are drastically change and impact was noted globally, they are the primary producer of fossil fuel globally. Those countries need to follow an alternate source of primary income with renewable energy strict policy implication to tackle all the worsen climate condition with GHG (Mahmood & Furqan, 2021).

Further regulations and strict policy implications with GHG emission watchdog institutions, natural resources rent, and Oil rent are needed to be developed and REC technological adaptation and upgradation are mandatory to decrease the GHG emission (Agboola et al, 2021). It can be concluded on the best of our knowledge, that the literature of oil rent is emerging, and no sign of oil rent strict policy implication yet to be developed in the literature.

3.3. Literature Review

Ng et al. (2022) expediate research on "unemployment rate, clean energy, and ecological footprint in OECD countries", over a period of 1995-2015. Experiential criteria of research were covered under the "Common Correlated Effect Mean Group (Henceforth, CCEMG) and Augmented Mean Group (AMG)" models. The OECD countries data of Ecological Footprint from Global Footprint Network, GDP per capita (Y), Square of GDP per capita (Y^2), Clean Energy, and Unemployment rate were obtained World Development Indicator and transformed

into panel data. EKC hypothesis were reevaluated for Ecological Footprint as indicator of environmental reduction, Another Environmental Phillips Curve (henceforth, EPC) hypothesis were used to evaluate the ecological footprint relation to clean energy. With the exception of EF and CF, which were stationary at level, the second-generation panel unit root test (CIPS) technique was used to find Stationary among the variables after analyzing the CD tests to look for cross-sectional dependency and CSD among series. Additionally, the model's p-value supports the use of CCEMG and AMG to repair errors and support cointegration over the long term. Therefore, the empirical evidence of research pointed that in case of OECD countries EKC is not valid due to presence of positive trade-off between unemployment and environmental degradation. While EPC hypothesis were found valid in OECD countries which supported that negative trade-off between unemployment and ecological footprint as 1% increase in unemployment can decrease ecological footprint by 0.6-0.7%. Thus, it is palpable through analysis that all the results are statistically significant and confirms the existence of EPC model in OECD countries in the long run. In the case of OECD nations, they have argued that adopting green technologies, especially in the clean energy sectors, can be a guarantee for environmentally sound development and sustainable economic growth.

Liu & Feng (2022) conducted research on "the effects of nurturing pressure and unemployment on carbon emission: Cross-country evidence over a period of 1991-2022". Experiential criteria of research were covered under the Panel-correlated Standard Error (henceforth, PCSE) models. The data of 77 countries of "Carbon Emission, GDP per capita, Population size, Energy Intensity, Percentage of Urban Population, Age Dependency Ratio, and Unemployment Rate" were obtained World Bank (IBRD) and BP Statistical Yearbook, transformed into panel data. The CD, autocorrelation and heteroscedasticity approach were utilized to discover the cross-sectional correlation and found significant, the discovered the presence of autocorrelation within the group at Global and regional level, and heteroscedasticity presence among panel data were rejected within the data. Moreover, due to the missing values among panel "CIPS panel unit root test rejected the presence of unit root among the series at first difference", which support the cointegration in long run by using PCSE model and Driscoll-Kraay, standard error adjustment method was used to avoid biasness. Therefore, the empirical evidence of PCSE model pointed that in case of 77 countries found negative trade-off between ADR, UR, and Carbon degradation as 1% increase in ADR, UR can decrease 0.0758-0.0175%

carbon degradation. While EPC hypothesis were found valid in OECD countries which supported that unemployment and environmental degradation had a negative relationship. Thus, it is profound under this research that all the results are statistically significant and confirms the existence of EPC model in "OECD countries in the long run". They concluded in case of OECD countries at Global and regional level that negative impact of unemployment in future can cause "sustainable economic and social development even generate political and social crises".

Tariq et al. (2022) denoted research on the "exploring the existence of environmental Phillips curve in South Asian countries over a period of 1991-2019". Experiential criteria of research were covered under the Pool Mean Group-Auto-regressive Distribution Lag (Henceforth, PMG-ARDL) models. The data of South Asian countries of "Unemployment rate, Gross Domestic Product, Population Growth, Renewable Energy, Non-Renewable Energy, and Ecological Footprint" were obtained World Development Indicator (WDI) transformed into panel data. The CD among all the variables were found significant in South Asian countries. Moreover, CIPS and CADF unit root found all the variables integrated and significant, which support the cointegration in long run. Therefore, PMG-ARDL model empirical evidence pointed that in case of South Asian countries found relationship between, UNE and EF as 1% increase in UNE can decrease -1.01%% carbon degradation. While EPC hypothesis were found valid in South Asian countries which supported that unemployment and ecological footprint found negative relationship. The stability of model was denoted by the value of ECT which were found negative -0.38% and 1% significant at level. Thus, it is noted that the research that all the results are statistically significant and confirms the existence of EPC model in South Asian countries in the long run. They settled in case of South Asian countries that the negative impact of unemployment in future can cause negative impact on economic development and to avoid this adoption of sustainable technologies and social development with reconsideration of urbanization policies can contribute.

Anser et al. (2021) comprehended research on the "exploring a new perspective of sustainable development drive through environmental Phillips curve in the case of the BRICST countries over a period of 1992-2016". Experiential criteria of research were covered under the Pool Mean Group-Auto-regressive Distribution Lag (Henceforth, PMG-ARDL) models. The data of BRICST countries of "Ecological Footprint, Gross Domestic Product per capita, Non-

Renewable Energy, Renewable Energy, Unemployment rate and Population Growth (POP)" were obtained World Development Indicator and Global Footprint Network transformed into panel data. The CD in the series among all the variables were present in BRICST countries. Moreover, to analyse the existence of unit root, CIPS and CADF unit root test were used and found all the variables integrated and stationary, which support the cointegration in the research and long run relationship among ecological footprint and rest of the variables. Therefore, PMG-ARDL model's empirical results specify that within BRICST countries "found negative and statistically significant relationship between, UNE and EF" as 1% increase in UNE can increase 0.16% of environmental degradation. While EPC hypothesis were found valid in BRICST countries which pointed that unemployment and environmental degradation had negative relationship. The permanence of model was denoted by the value of ECT which were found negative -0.60% and significant. Hence, it is conveyed that "the empirical results of the study are statistically significant and confirms the existence of "EPC model in BRICST countries" in the long run". Anser et al. (2021) & (Ipek, 2021) have suggested that in case of BRICST countries should avoid the policy which can cause unemployment in future and the adoption of sustainable technologies, R&D for sustainable production and technologies which can promote use of renewable energy could be effective without further causing any harm on the rate of unemployment with in the BRICST countries.

Kashem & Rahman (2020) conducted research on "Environmental Phillips curve: OECD and Asian NICs perspective over a period of 1990-2016". Empirical criteria of research were covered under the Panel-correlated Standard Error (henceforth, PCSE) models. The data of 30 countries of GDP, Unemployment Rate, GDP and trade-GDP ratio and Carbon Emission, were obtained from United Nations, World Development Indicator and OECD, transformed into panel data. The "Cross Dependence (CD) and panel unit root test" approach was used to discover the cross-sectional correlation and stationarity by Fixed Effect Model (FEM) which confirms that the stats of the research are stationery and CD. Moreover, PCSE model were utilized, which support the cointegration in long run. Therefore, the empirical evidence of PCSE model pointed that in case of 30, it is profound under this research that all the results are statistically significant and confirms the formation of EPC model in 30 OECD countries in the long run. They concluded in case of OECD countries experiencing unemployment problems can experience "non-sustainable economic and social development and even generate political and social

crises". Finally, the authors asserted that, the during financial and economic crisis the economies will experience lesser pollution levels due to persistence of higher levels of unemployment rate caused by the economic crisis.

Wang & Li (2021) conducted research on "the effects of population aging, life expectancy, unemployment rate, population density, per capita GDP, urbanization on per capita carbon emissions over a period of 1992-2016". Experiential criteria of research were concealed under "the Stochastic Impact by regression on Population, Affluence and Technology (Henceforth, STIRPAT) models". The data of 154 countries of Carbon Emission, Population aging, Population urbanization, Gross Domestic Product per capita, population density, Unemployment rate and life expectancy were obtained World Bank transformed into panel data. The cross-section correlation and the stationarity of data were found among the series of 154 countries. Moreover, unit roots were analysed and cointegration were found and all the variables are integrated and stationary in long-run. Therefore, OLS model's empirical results indicated the negative relationship between unemployment and carbon emission, as 1% increase in unemployment rate can increase 0.010% of carbon emission. Hence, it was denoted that "unemployment rate has a negative impact on carbon emission among developed, developing and under developing countries". They research pointed on to adopt policies of sustainability of environment, sustainable energy efficiency to combat unemployment and financial support for developing and under developing countries for emission reduction.

Bhowmik (2022) did research on "Applying a dynamic ARDL approach to the Environmental Phillips Curve (EPC) hypothesis amid monetary, fiscal, and trade policy uncertainty in the USA over a period of 1985-2018". Empirical criteria of research were covered under the ARDL models. The data of USA of GDP, Industrial Production Index, Energy Consumption, Unemployment Rate, Monetary Policy Uncertainty Index, Fiscal Policy Uncertainty and Trade Policy Uncertainty, were obtained from Federal Reserve Economic Database, EIA, Energy Policy Uncertainty Index, transformed into panel data. The panel unit root test method was used to determine the cross-sectional correlation and stationarity by "GLS-ADF unit root test, which indicated that the data of the study are stationery and CD". Moreover, ARDL model were employed, which support the cointegration in long run. Therefore, the empirical evidence of ARDL model shown that in case of USA, negative relationship between

unemployment and carbon emission were found in long-run, as 1% increase in unemployment rate can increase 0.023% of carbon emission and confirms the existence of EPC model. Thus, it was noted under this study that all the results are statistically significant with the value of ECT -0.07% in the long run. They have concluded that innovation policy in environmental technologies, adoption of sustainable employment and open market to new start-up, and while making policies unemployment considered as the main impacting agents on carbon emission.

Tanveer et al. (2022) did research on "Validation of environmental Philips curve in Pakistan: a fresh insight through ARDL technique over a period of 1975-2014". Empirical criteria of research were covered under the ARDL models. The data of Pakistan for "Carbon Emission, Methane Gas, Ecological Footprint, Unemployment Rate, Energy Consumption, Foreign Direct Investment, GDP, and Globalization Index" were obtained from World Bank, Global Footprint Network and Swiss Economic Institute, transformed into panel data. The Structural break test was used to determine the cross-sectional correlation and series is stationary in ZA unit root tests, F statistics bound value shows that the data of the study are stationery and co-integrated. Moreover, "ARDL model were used, which support the cointegration in long run. Thus, the empirical evidence of ARDL model shown that in case of Pakistan, negative relationship between unemployment and carbon, methane emission and ecological footprint were found in long-run, as 1% increase in unemployment rate can increase 0.0197% of carbon emission and confirms the existence of EPC model". The ECT value were found negative in the "long run". They have settled that the government should reconsider on environmental factor responsible rate of unemployment, sustainable and renewable energy production.

Naqvi et al. (2022) did research on "Towards a green economy in Europe: does renewable energy production has asymmetric effects on unemployment? over a period of 1991-2019". Empirical criteria of research were covered under the NARDL-PMG models. The data of European Economies for Unemployment Rate, Renewable Energy production, GDP, Investment, and Technological Innovations were obtained from World Bank and converted into panel data for the research. The panel "unit root test approach was utilized to check the cross-sectional and correlation among the series. NARDL-PMG model were used, ECM & Kao test support the cointegration in long run". Thus, the empirical evidence of NARDL-PMG model shown that in case of European Economies negative relationship were found between

unemployment and renewable energy production in long-run, as 1% increase in renewable energy production can plunges 1.029% of unemployment Rate. The have concluded that the innovation technologies must be more focused and R&D in sustainable energy production, sustainable policies for job creation must be reconsidered.

Islam et al. (2021) did research on "the effects of carbon emissions, rainfall, temperature, inflation, population, and unemployment on economic growth in Saudi Arabia: An ARDL investigation over a period of 1990-2019". Empirical criteria of research were covered under the ARDL models. The data of Saudi Arabia for "GDP, Inflation, Unemployment Rate, Population, Rainfall, Temperature, and CO2 emission was obtained from World Bank, General Authority of Meteorology and Environmental production and converted into panel data for further study". The panel "unit root test approach was utilized to check the cross-sectional and correlation among the series". ARDL model were used, test support the cointegration in long run. Therefore, the empirical evidence of ARDL model revealed that in case of Saudi Arabia negative relationship were found between unemployment, CO2 emission, and GDP in long-run. Thus, the value of ECT were found negative -1.79% and model and results were stable. Recommendation denoted as more scientific technologies and R&D needed to invest to combat the effect of annual rainfall for a sustainable economic growth to decrease the carbon emission.

Ibrahiem & Sameh (2020) conducted research on "How do clean energy sources and financial development affect unemployment? Empirical evidence from Egypt over a period of 1971-202014". Empirical criteria of research were covered under the ARDL and VECM models. The panel data which combine time series and cross-sectional data of Egypt for GDP, Unemployment Rate, Alternative and nuclear energy, and population growth were obtained from World Bank for further study. The stability of the variable and correlation and stationery were found among the series. ARDL model were used, test indicated to use the cointegration in long run. Therefore, the empirical evidence of ARDL model revealed that in case of Egypt negative relationship were found between unemployment and clean energy source in long-run. Moreover, the VECM model based on cointegration indicated that short run unidirectional relationship presents among the variables. They have concluded that sustainable clean energy policies for micro business needed more investment and focused on creating sustainable job opportunities with sustainable growth.

Yu & XU (2019) conducted research and empirical results of the study indicated that GHG had a negative relationship between labor force and unemployment with a coefficient value of 0.364 for labor force and insignificant coefficient value for unemployment of their panel data and regression model in USA. Moreover, they have suggested that in case of USA, more carbon emission promotes the labor force into the economy to grow on another hand growing problem of gradation in long term will cause the increase in unemployment. Policies must be considered under the sustainable development patter to cope up with the coming problem of anthropogenic emission.

Sheraz et al., (2022) research for the year 2008-2018 on Belt and Road Initiative countries, an empirical model of two step GMM, results indicated that renewable energy consumptions had a positive relationship between carbon degradation to eradicate more emission. Second generation unit root of the series and Cross-sectional dependency were check and GMM methods results indicated that 1% increase in renewable energy consumption could help carbon degradation by 0.001% with a 5% of significance value among 64 Belt and Road Initiative (BRI) countries in long run. Bi-directional relationships were found among FD, REC, IQ, SEC, and CO2 variables of the study.

Khobai et al. (2020) conducted research on South Africa over a period of 1900-2014. Research approaches were followed was ARDL bound testing to analyze the relationship among the variable of panel data in long. Empirical results of the model indicated a positive relationship between REC and UNE, 1% investment in financial development can decrease a 0.08% unemployment rate. Results of their study were significant and stable, where ECT vale found - 0.69%. They have concluded that increase in labor intensive policies improve employment in long run, which expand the sustainable economic growth.

Nawaz et al. (2022) researched on Trilemma association of energy consumption, carbon emission, and economic growth of BRICS and OECD regions for a period of 1980-2016. They have taken CO2, renewable energy, Fossil fuel energy, GDP, GDP2, capital, and Trade openness as their variable and data were extruded from WDI. Empirical approaches were covered under ARDL, and methodological criteria were followed under IPAT model. They have discovered that REC has a positive impact in decreasing carbon emission in long rum for BRICS and OECD countries. Pairwise regression coefficient illustrated that an 1% increase in REC will improve

CO₂ by 0.812%. Stability of the model were check by the value of ECT -0.08%. Concluding remark of the research were to be focused on REC usage as BRIC & OECD countries growth depends on energy production and usage, to enhance the capacity of energy renewable and non-renewable energy intensity policies needs more R&D and investment.

Raza (2022) indicated in their researched entitled as "Towards a sustainable development: econometric analysis of energy use, economic factors, and CO₂ emission in Pakistan during over a period of 1975–2018". The time series data of Fossil Fuel energy consumption, Carbon emission, GDP, Service Value Added, Fiscal deficit, Rural and urban unemployment, Rural and urban population were extracted from Pakistan Energy Survey, Pakistan Energy Yearbook, EDGAR, and World Bank. Empirical approach of ARDL and VECM GG "were used to investigate the relationship among variables in long run". They found that "Fossil fuel energy consumption has a negative effect on Carbon emission as 1% increase" in FFEC can increase Carbon emission by 0.311% with 1% increase in rural and urban unemployment can increase Carbon emission by 0.04% and estimate of the result were found a long-term significant association among the variables with significant ECT value. VECM mode approach identify the bidirectional causality and cointegration among FFEC, urban and rural unemployment with Carbon emission in long term. A negative relationship was found among carbon emission, fossil fuel consumption and unemployment, it was noted that FFEC, unemployment and FD is increasing carbon emission in long-run. CUSUM and CUSUMQ significant value indicated the stability of the model. Recommendations of the study were to adopt sustainable clean energy to combat the rising carbon emission and technological advancement in energy sector is necessary.

Mensah et al. (2018) adopted FMOLS to estimate the effect of innovation on carbon emission for a period of 1996-2014 in OECD countries by STIRPAT model and empirical results of the research indicated that renewable energy consumption decreases the carbon emission among OECD countries except 6 countries where REC increase the carbon emission rate (NRES possibly used in electricity generation).

Dong et al. (2019) indicated in their research where empirical investigation based on "cross-section dependence, slope homogeneity, unit root, and cointegration test (henceforth, CCEMG & AMG) along with STIRPAT model were analyzed a panel data for 128 countries over a period of 1990-2014". Estimated research test indicated a strong CD, unit root,

cointegration and stationary were found in the series which directed to use CCEMG & AMG model for long run. Thus, the estimates of the results were found that CO₂ is negatively related to NREC, which means 1% increase in RE decreases up to 0.4497% by AMG, 0.5832% by CCEMG in CO₂ emission in long run. D-H panel "bidirectional causality indicated a bidirectional causality between CO₂ emission and renewable energy at global". Hence, "it was noted that renewable energy consumption has a significant negative impact on CO₂ emission". They have suggested that every country should adopt the policy which increases the use of effective renewable energy policies.

Sebri & Ben-Salha (2014) indicated in their research on BRICS countries for a period of 1971-2010, a time series data empirically "investigated through ARDL and Granger Causality methodology". The empirical result of the model explained with significant negative of ECT, Granger causality indicated existence of bi-directional causality among the economic growth and renewable energy consumption in BRICS countries. Empirical results of the research explained that REC has a significant effect on CO₂ emission in BRICS countries.

3.3.1. Greenhouse Gas Emission

The impact of GHG emission on climate condition are bidirectional based on the publish literature. The empirical research of Ram et al, (2018) indicated the high cost of energy generation and storage and an RE storage and consumption could possibly the alternate for 85% of global electricity consumption and storage in G20 countries. (Qiao et al, 2019) indicated the increase in agricultural activities causing GHG, while RE decreasing the GHG emission. (Mardani et al, 2018) denoted that applying "a model known as adaptive neuro-fuzzy inference system (ANFIS) the interrelationship of energy consumption and economic growth could be monitored and the real time policy adaptation and recommendation gives a productive outcome".

Additionally, the above-mentioned research indicated important roles in torching the outcomes of increasing GHG problem. Moreover, Erdogan et al. (2020) focused on the technological innovation and policy development in G20 countries, Kodjak, (2015), empirically indicated the reduction in the consumption of fossil fuel for vehicle through technological

innovation can reduce the GHG in G20 countries (Codal et al, 2021) focused on multidirectional approach to tackle the growing problem of GHG. The outcome of GHG policy implication in reduction playing an important role in G20 countries through multiple goal and development agenda (Elzen et al, 2019).

3.3.2. Factors affecting Greenhouse Gas Emissions

The greenhouse gases emission on a macro level released by the heavy industries, energy consumption from non-renewable energy, economic growth, and urbanization, while micro scale factors considered rest like, forest removal, soil erosion, burning crops, construction, dairy industries, unorganized human migration across borders, crackers and many more which still did not noticed and considered due to lack of data. This study has mentioned previously the literature connecting the theme of the research. Moreover, the few of the notable literature has considered for specific area are as follows:

- **Economic Growth**

The two third of the world's economic development are covered by the G20 countries. The growing economy needs developed infrastructure and modern technology for a speedy growth which was noted down by the empirical research of Yao et al, (2015) on G20 countries and pointed out that the main factor of emission is due to the speedy economic growth activities.

- **Population Density**

Population in G20 countries is around 60% of the total world population, which is increased a total of 40% in last 30 years (UN, 2019). The amount of GHG emission release yearly is equal to 82% of total GHG emission of the world. The increasing population demand more resources, high production, developed heavy industries, more electricity and which in whole scenario causing release in GHG emission Abdouli et al, (2017). Based on the UN report policy recommendations of (2019) the G20 countries population in 2050 will be 5 billion, which will cut the emission by half.

• "Renewable Energy Consumption"

This section focuses on research analyzing the effects of using renewable energy on ecological footprint. Due to popularity gained by the panel data research his study will be considering the research of He et. al (2022), they examined the dynamic relationship among environmental sustainability by considering the variables "REC, economic growth, oil rent, natural resources and GHG in case of China over a period of 1971-2018" by using panel data approach with ARDL model for long-run. Their empirical estimated indicated the REC and oil rent helping GHG emission reduction in long and short run, they have concluded that transformation of energy from Fossil energy to REC is necessary and dependency of natural resource needed to be reconsidered. Thus, the study had a significant result by using selected variables. Boluk & Mert, (2014) indicated in research on EU-16 over a period of 1990-2008, "that the EKC is not valid in EU-16 countries", that is, REC reduces the GHG emission in comparison of fossil energy. Thus, transformation in the energy sector is necessary to combat the GHG emission problem in EU-16 countries.

Table 12. Summary of Literature Review

Authors	Country	Period	Variables	Methodology	Conclusion
Ng et al. (2022)	OECD	1995-2015	EC, GDP, GDP ² , CE, UNP,	CCEMG, AMG, EKC EPC	EPC Valid
Liu & Feng (2022)	77 Countries	1991-2022	CO2, GDP, PS, EI, PUP, ADR, UNP,	PCSE, EPC	EPC Valid in OECD
Tariq et al. (2022)	South Asian Countries	1991-2019	UNP, GDP, POP, RE, NRE, EF,	PMG-ARDL, EPC	EPC valid
Anser et al. (2021)	BRICST	1992-2016	EF, GDP, NRE, REC, UNP, POP	PMG-ARDL, EPC,	EPC Valid

Kashem & Rehman (2020)	OECD	1990-2016	GDP, UNP, Trade-GDP, CE,	FEM, PCSE, EPC,	EPC Valid
Wang & Li (2021)	154 countries	1992-2016	CE, PA, PU, GDP, PD, UNP, LE,	STIRPAT, OLS,	Negative Relationship GD and UNP
Bhowmik (2022)	USA	1985-2018	GDP, IPI, EC, UNP, MPUI, FPU, TPU,	ARDL, EPC,	EPC Valid
Tanveer et al. (2022)	Pakistan	1975-2014	CE, CH4, EF, UNP, EC, FDI,	ARDL, EPC,	EPC Valid
Naqvi et al, (2022)	EU	1991-2019	UNP, REP, GDP, I, TI,	NARDL-PMG	Negative UNP and REP
Islam et al, (2021)	Saudi Arabia	1990-2019	GDP, CPI, UNP, PR, RAFL, TEMP, CO2	ARDL	Negative UNP, CO2, GDP
Ibrahim & Sameh (2020)	Egypt	1971-2014	GDP, UNP, AER, NER, POP,	ARDL, VCM	Negative & Unidirectional Relationships among the Variables, UNP and Clean Energy
Yu & XU (2019)	USA	2000-2015	EKC, CE, GDPGR, UNP, GDP, EC	Panel Regression	EKC valid, Negative relationship GHG and UNP
Sheraz et al, (2022)	64-BRI Countries	2003-2018	CO2, FD, RE, Globalization, IQ,	GMM	RE, Globalization, CO2 Positively EQ, Bidirectional relationship

					FD, RE, IQ, with CO2, Unidirectional relationship Globalization, CO2
Khobai et al, (2020)	South Africa	1900-2014	REC, UNP, INV, GEXP, CRED,	ARDL	Positive relationships among REC and UNP
Nawaz et al, (2022)	BRICS, OECD	1980-2016	CO2, RE, FFE, GDP, GDP2, Capital, TOP,	ARDL	Positive relationships REC and CO2
Raza (2022)	Pakistan	1975-2018	FFEC, CO2, GDP, SVA, FD, RUEUNP, REPOP,	VECMGG	Positive relationship FFEC, CO2, UNP
Mansah et al, (2018)	OECD	1996-2014	GDP, REC, CO2, NREC,	EKC, FMOLS	Negative relationship GDP and CO2 Negative relationship REC and CO2
Dong et al, (2019)	128 Countries	1990-2014	CO2, PS, GDP, EI, NREC, RE	AMG, CCEMG,	Bidirectional Relationships RE and CO2 globally, Negative Relationships RE and CO2,
Sebri & Ben-Salha (2014)	BRIC-4	1971-2019	GDP, REC, TO, CO2,	ARDL, FMOLS, DOLS,	Bidirectional Relationship GDP, REC, CO2, Positive relationship GDP and REC

3.3.3. An Overview of Literature Review

Over a past decade researcher has analysed factors responsible for greenhouse gas emission. There are wide range of research regarding impact of several factors on greenhouse gas emission in the empirical literature. The evidence based on the literature reviewed in this chapter suggested that different variables have an impact on GHG such as, renewable energy and consumption, unemployment rate in an economy, environmental taxes, and resource rent mainly oil rent. Moreover, it was proclaimed that GDP of an economy has a vital role in GHG emission. In the light of literature review, most of the studies produced the negative relationships with unemployment and positive relationships with renewable energy consumptions, where oil rent is still in monitoring stage due its significant acceptance in literature. The recent advancement in the literature validated the Environmental Phillips Curve hypothesis in most of the countries except underdeveloped economies. The estimates of the previous studies pointed out that the economy size and GHG policy adoption in an economy, income level, human capital level, renewable energy intensity and consumption matters. Although, the data set and selection of methodology might affect the estimates significantly. Thus, most of the results indicated that the greenhouse gases emission is directly related to level of unemployment and renewable energy consumption.

3.4. Data and Model

In this section, initially the research presents the database and its source of extraction then it explains the methodology and model which is commissioned in the chapter of the thesis.

3.4.1. Data Source and Model

This research adopted an annual dataset for G20 countries covering the period of 1991-2020. This research aims to torch on the new determinants of environmental degradation and GHG by employing oil rent and UNP. G20 countries are as follows: "Argentina, Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Italy, Japan, Republic of Korea, Mexico, Russia, Saudi Arabia, South Africa, Turkey, United Kingdom, United State and European Union". A panel data approach unitized to determine the most significant factor

impacting GHG emission in the abovementioned group of countries. This research uses per capita ecological footprint as an ecological indicator. Moreover, we have selected 3 other variable which can have the significant effects on Greenhouse gas emission (Ecological footprint) quality based on the availability of data. Thus, Oil rent is the new variable in the research to identify the GHG emission in the empirical literature.

This chapter of the thesis extracted the data from the direct main source of world bank. Table below presents the variables used in this study with their unit, form, and source. We have taken the natural logarithm of GHG emission variable.

Table 13. Data Source & Description

Variables	Unit	Form	Source
Greenhouse Gas Emission (GHG)	Metric ton	Natural Logarithm	World Bank
Unemployment Rate (UNP)	% of total labor force	Percentage	World Bank
Renewable Energy consumption (REC)	% of total final energy consumption	Percentage	World Bank
Oil Rent (OR)	% Of GDP	Percentage	World Bank

Source: (World Bank, 2022)

3.4.2. Corelation Matrix

Correlation matrix defines the degree of correlation between the variables. For our model the correlation matrix is given below.

Table 14. Correlation Metrix

Variables	LnGHG	REC	UNP	OR
LnGHG	1.00	0.06	-0.26	-0.13
REC	0.06	1.00	-0.006	-0.20
UNP	-0.26	-0.006	1.00	-0.12
OR	-0.13	-0.20	-0.12	1.00

Source: Authors Calculation

The table above shows the "correlation between the variables taken in the model. The correlation" ranges between -1 and +1 value. Here, the correlation between gross domestic product and renewable energy consumption is positive while the correlation between gross domestic product, unemployment rate and oil rents are negative.

3.4.3. Descriptive Statistics

Descriptive statistics defines the general statistical information about the individual variables, such as mean, standard deviation, kurtosis, skewness etc.

Table 15. Descriptive Statistics of the Variables

Descriptive Statistics	LnGHG	REC	UNP	OR
Obs.	580	580	580	580
Max.	16.35	57.82	33.29	54.44
Min.	12.24	0.00	2.05	0.00
Mean	13.73	14.58	7.95	2.96
Std. Dev.	0.93	13.94	5.42	8.10
Skewness	0.98	1.40	2.62	4.21
Kurtosis	3.03	4.08	10.66	21.18
Jarque - Bera	94.46	218.65	2084.55	9702.96
J-B Prob.	0.00	0.00	0.00	0.00

Source: Authors Calculation

The table below shows the "descriptive statistics of the following variables taken in the model of the G-20 countries from 1991-2020".

The data of all the variables of these G-20 has 580 number of observations. The "greenhouse gas emissions, unemployment rate, renewable energy consumption, and oil rents" data is centered over 13.73, 14.58, 7.95, and 2.96, percent respectively. The statistic standard deviation which measures the spread or the dispersion of the dataset of greenhouse gas emissions, unemployment rate, renewable energy consumption, and oil rents, in relation to its mean is 0.93, 13.94, 5.42, and 8.10 respectively.

The skewness is a statistic which measures the presence of asymmetry in the distribution of the dataset around its mean. For a normally distributed series, the value of skewness is zero. Therefore, the positive/negative value of skewness suggests "that there is long tail in the right/left side of the distribution". Thus, "greenhouse gas emissions, unemployment rate, renewable energy consumption, and oil rents" shows long tail on the right side of the distribution.

The kurtosis is a statistic which measures the presence of peaked-ness or the flatness of the distribution of the series. For a normally distributed series the value of Kurtosis statistic is 3. Therefore, the estimated Kurtosis values of all the variables shown above indicates the presence of normally distributed peaks for greenhouse gas emissions and unemployment rate and tip like peak for renewable energy consumption and oil rents.

After estimating that the distribution has skewness as well as peak, it is indicated that the series distribution is normal. The Jarque-Bera probability confirms the presence of normal distribution in all the dataset from 1991 to 2020.

3.4.4. The Econometric Model

This study is following the (Kashem & Rehman, 2020) research, we are outlining estimated model which defines environmental degradation as a function of unemployment with other controlled variables. The model of environmental degradation postulates positive relationships among pollution and income stated as:

$$P = a + by$$

In the above equation p represents for pollution and y represents for output.

Followed by "Okun's law, unemployment is as an inverse function of income or output".

$$u = c + dy$$

In the above equation u represents as unemployment rate.

Through the above mentioned two equations, we implicate that environmental degradation, pollution levels, and unemployment are contrariwise related to each-other.

$$p = e - gu$$

Moreover, following previous literature, we considered the GHG as a dependent variable and UNP, REC and OR are independent variables in this model (He, et al, 2022; Liu et al, 2022; Bhowmik et al, 2022; Kashem & Rehman, 2020; Anser et al, 2021).

$$GHG = f(UNP, REC, OR) \quad (15)$$

We have transformed GHG series by natural logarithm to get the consistent and stable estimates (Shahbaz et al, 2013), while all the independent variables are in percentage form. The equation for estimates as follows:

$$LnGHG = a_0 + \alpha_{1i} UNP_{it} + \alpha_{2i} REC_{it} + \alpha_{3i} OR_{it} + \varepsilon_{i,t} \quad (16)$$

Hypothesis of the research are as follows:

Hypothesis 1: GHG and UNP follows EPC hypothesis in G-20 countries i.e., $\alpha_{1i} < 0$.

Hypothesis 2: REC is negatively impacting the GHG emission in G-20 countries i.e., $\alpha_{2i} < 0$.

Hypothesis 3: OR is negatively impacting the GHG emission in G-20 countries i.e., $\alpha_{3i} > 0$.

3.4.5. Justification of the Hypothesis & Variables

Since the G-20 group comprises of countries with emerging economies, therefore it is experiencing massive unemployment crisis along with the greenhouse gas emission problem. The data, literature reviews, and the theoretical background demonstrated that greenhouse gas

emissions are impacted by different economic indicators such as, economic growth, rising unemployment rate, inefficient energy consumption, unmonitored oil rents etc., globally. Considering the outcomes of the literature reviews and theoretical background we have taken unemployment rate, renewable energy consumption, and oil rents and tried to check their impact of the greenhouse gas emissions of G-20 countries.

3.4.6. Panel Data Plot of the Greenhouse Gas Emissions

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The Greenhouse Gas Emissions rate of G-20 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see China has been the leading greenhouse gas emitter followed by USA and EU in the G-20 group countries.

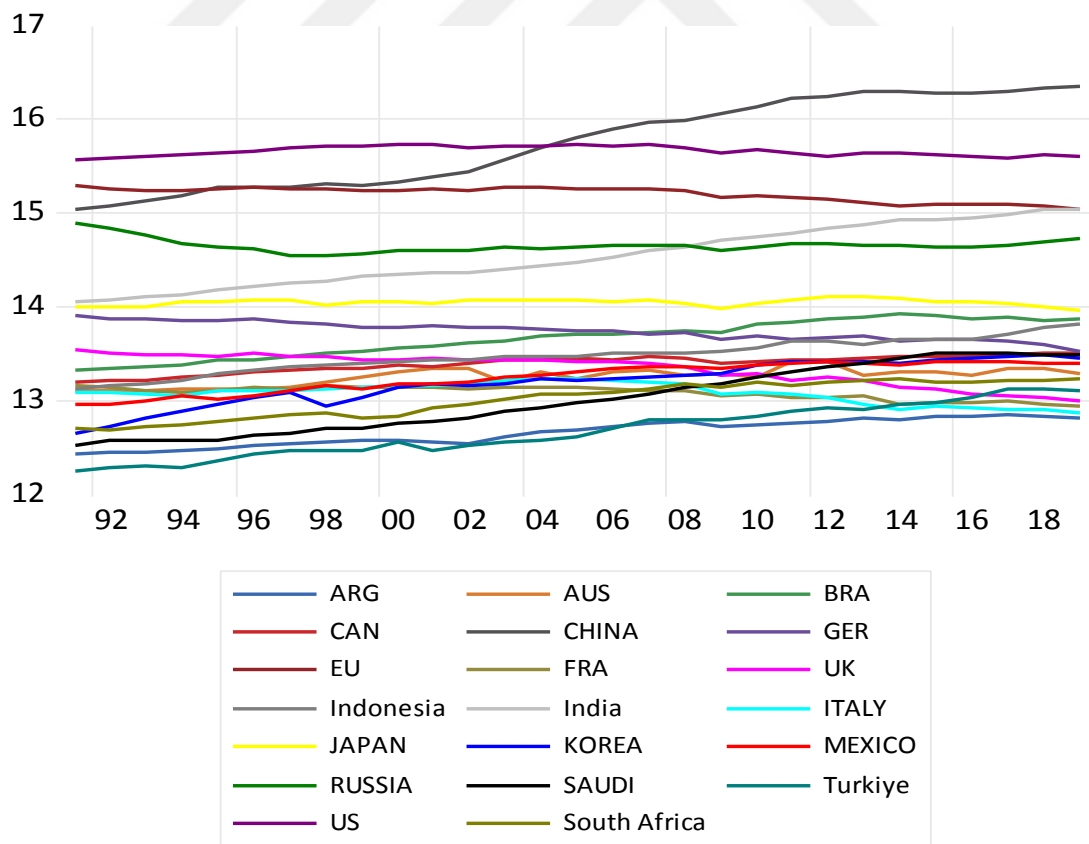


Figure 5. Panel Data Plot of the Greenhouse Gas Emissions

3.4.7. Panel Data Plot of the Unemployment Rate

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The unemployment rate of G-20 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see that South Africa is experiencing the highest unemployment rate around 28%, followed by Argentina which is around 10%. Overall, we can see all the G-20 group countries are experiencing massive unemployment crisis.

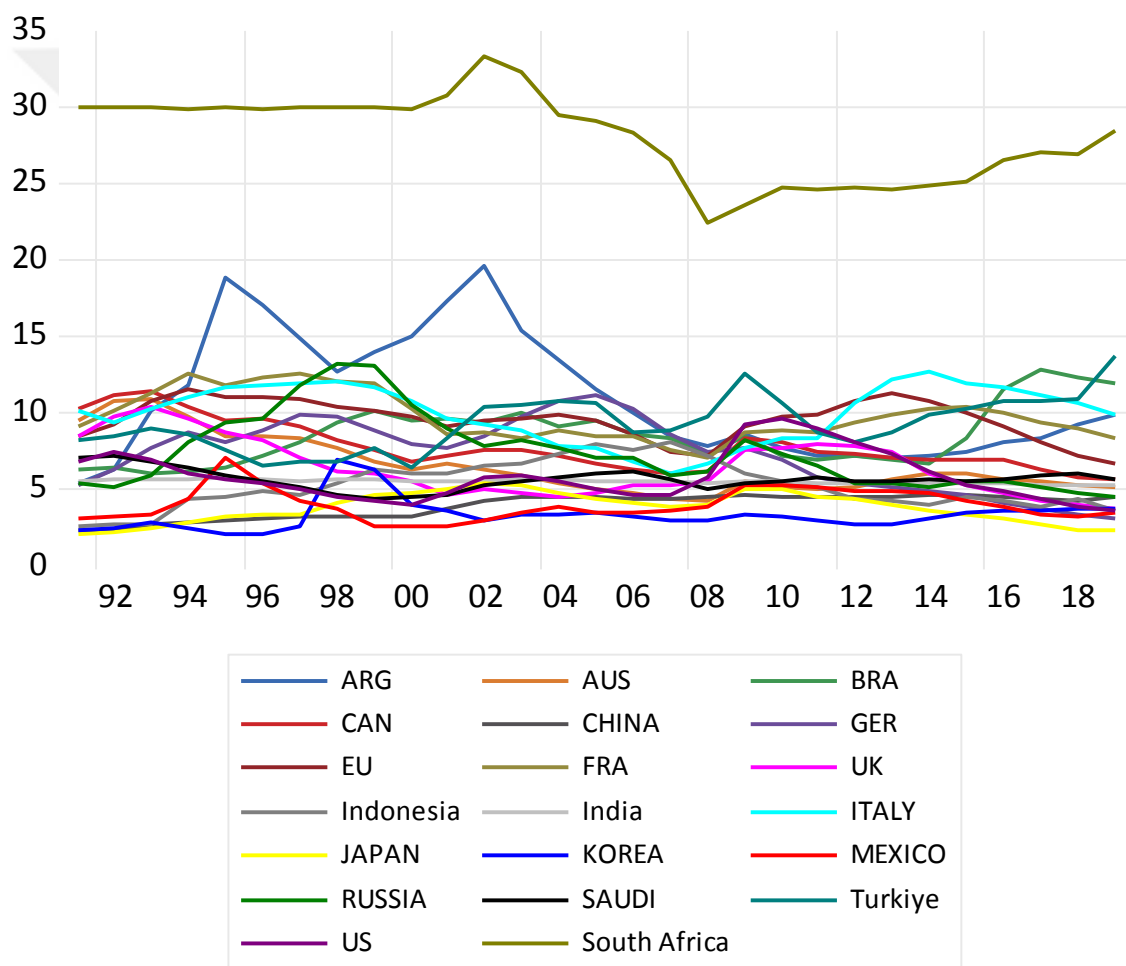


Figure 6. Panel Data Plot of the Unemployment Rate

3.4.8. Panel Data Plot of the Renewable Energy Consumption

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The Renewable Energy

Consumption rate of G-20 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see that Brazil has been leading in renewable energy consumption followed by India and Indonesia in the G-20 group countries. Overall, almost all the countries are increasing their renewable energy consumption.

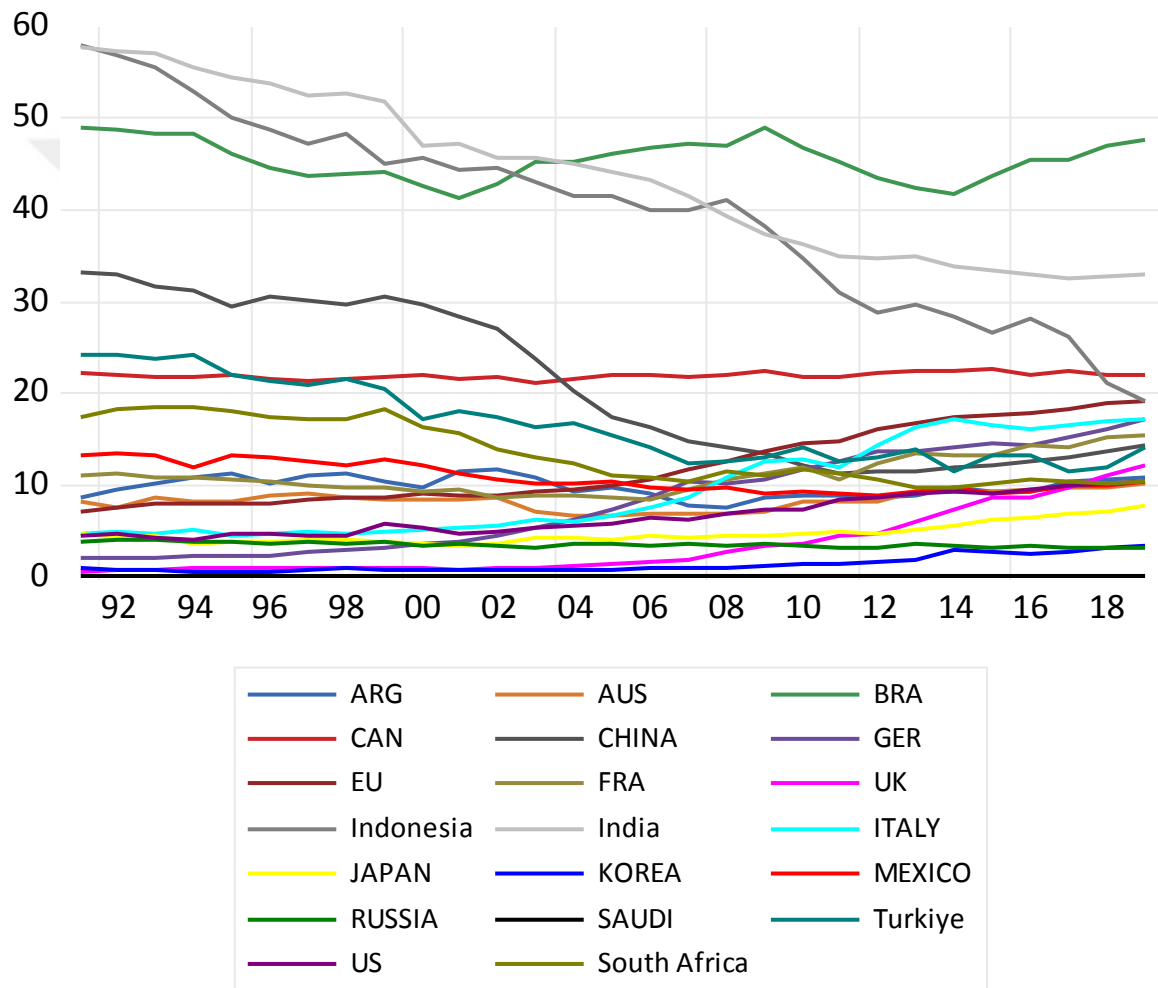


Figure 7. Panel Data Plot of the Renewable Energy Consumption

3.4.9. Panel Data Plot of the Oil Rents

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The Oil Rents of G-20 countries through the panel data plot from 1991-2020 can be seen below. From the graph we

can see Saudi Arabia has been the leading in Oil Rents followed by Russia in the G-20 group countries.

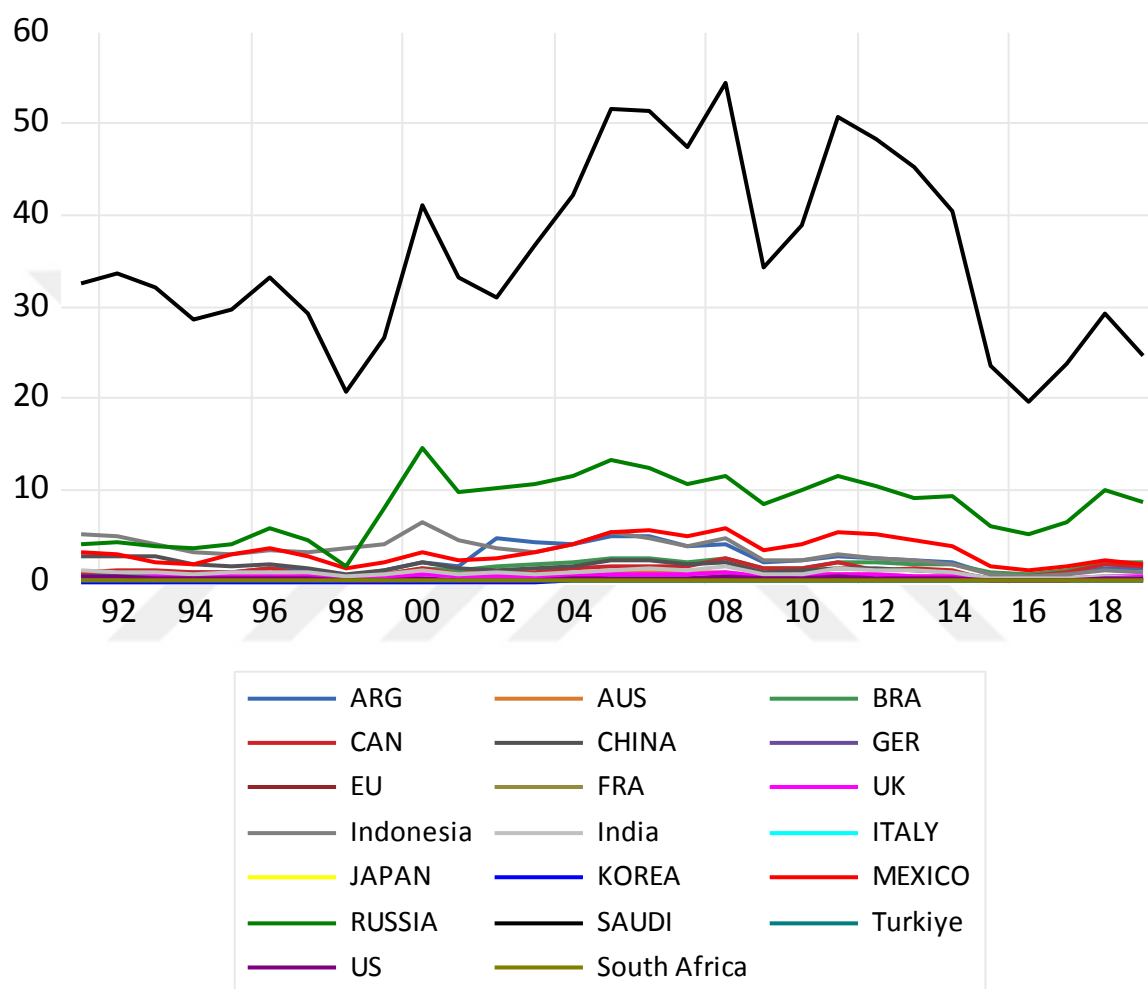


Figure 8. Panel Data Plot of the Oil Rents

3.5. Methodology

Updated and consistent econometric techniques advancing the research by using panel data approach, considering cross-section dependency. In this chapter of the research, we adopted the advanced panel data techniques described in subsections. Following steps of the thesis explain "cross-section dependence test, panel unit root test, First and second generations panel cointegration test, slope heterogeneity test".

3.5.1. "Cross-section Dependence in the Series"

In a panel data approach analysis testing CD is important step. In case of ignoring CD in the series can lead insignificant and misleading estimates (Dogan et al, 2017). We used a "bias-corrected scaled LM (Lagrange Multiplier) test developed by Baltagi et al. (2012) to avoid the CD issues in the series".

$$\text{Bias - corrected Scaled LM} = \sqrt{\left(\frac{1}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T_{ij} \widehat{P}_{ij}^2 - 1) - \frac{N}{2(T-1)} \quad (17)$$

In the above-mentioned equation, N represent the number of cross-sections, T represents the time dimensions. Moreover, $\widehat{P}_{ij}^2$ indicates the pair-wise correlation coefficient among the residuals. The adopted "CD test has an asymptotic standard normal distribution. We have taken in this analysis, the null of no cross-section dependency in this test" (Baltagi et al. 2012).

In case of CD in the series, a second-generation panel unit root tests should be used. Therefore, first-generation unit root test has to be analyzed in case CD did not find in the series.

3.5.2. IPS Panel Unit Root Test

"Linear panel unit root literature has two common types of analysis in the literature, known as, First-generation, and Second-generation panel unit root tests". In the literature, First-generation unit root test was introduced, and CD was not included in the panel.

For further details follow the previous chapter. The "test statistics $\bar{t}$ of the IPS panel unit root test obtained by taking an average of Augmented Dickey-Fuller (ADF)" test:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^N t_{pi} \quad (18)$$

Where t_{pi} indicates the "individual t -statistics in the above equation. The null hypothesis of the IPS test pointed that each series in the panel have a unit root" (Im et al, 2013; Baltagi, 2013).

3.5.3. CIPS Panel Unit Root Test

The "second-generation panel unit root test known as CIPS developed by Pesaran (2007) which consider the CD in the series". For further details follow the previous chapter. The statistics justification can be achieved by cross-sectional average of t_i as follows:

$$CADF = t(N, T) = \frac{\Delta y_i^l \bar{M}_i y_{i-1}}{(\Delta y_{i-1}^l \bar{M}_i y_{i-1})^{1/2}} \quad (19)$$

which is transformed into CIPS by averaging it as described below.

$$CIPS = N^{-1} \sum_{i=1}^n t(N, T) \quad (20)$$

In the above equation t_i represents as individual CADF statistics. By obtaining the CIPS statistics, value needs to be compared with the critical value obtained by Pesaran (2007). Thus, if all individual within panel data have a unit root validate the null hypothesis, meanwhile alternate claims that at least single individual is stationary.

3.5.4. Pedroni (1999) Panel Cointegration Test

This chapter of the research used the first-generation panel cointegration test known as Pedroni to obtain the proof of cointegration in the long-run relationship among the panel. Thus, null hypothesis of no cointegration and alternate hypothesis is cointegration present among the panel. Following statistics of the analysis presented as:

$$Y_{it} = \alpha_{it} + \delta_i t + \gamma_{2i} E_{it} + \gamma_{2i} L_{it} + \gamma_{3i} K_{it} + \varepsilon_{it} \quad (21)$$

In the above-mentioned statistics, " i represents the number of individuals, t represents the time, α_{it} and δ_i indicates the fixed effects and trend, ε_{it} represents residual estimates in the panel" (Pedroni, 1999 & 2004).

3.5.5. Westerlund (2007) Panel Cointegration Test

Previous empirical literature pointed out to use the second-generation cointegration test the "cross-sectional dependency in the residual model among the variables for the long run". This research adopted the cointegration test developed by Westerlund, (2007) which analyze

"the error correction term group mean (G_τ and G_a) and panel (P_τ and P_a) is equal to zero in a panel error-correction model". The test statistics are obtained from Westerlund (2007) and modified as our model required:

$$\Delta GHG_{i,t} = \alpha_i^C + \lambda_i^C (GHG_{it-1} - REC_{it-1} - \beta_i^C UNP_{it-1} - \gamma_i^C OR_{it-1}) + \sum_{j=1}^m \theta_{i,j}^G \Delta GHG_{it-j} + \sum_{j=1}^n \delta_{i,j}^G \Delta UNP_{it-j} + \sum_{j=1}^p \phi_{i,j}^G \Delta REC_{it-j} + \sum_{j=1}^n \vartheta_{i,j}^G \Delta OR_{it-j} + \mu_{i,t} \quad (22)$$

In the above equation $\lambda_i^C = -\alpha_i \beta_i^C$. If $\alpha_i < 0$ $\alpha_i > 0$ represent the value of error correction term. The rejection of null hypothesis for group and panel test suggests cointegration in at least one and all cross-sectional within the countries (Westerlund, 2007).

3.5.6. Slope Heterogeneity Test

Empirical literature, suggested to test the stability of the model by adopting the slope heterogeneity test developed by Pesaran & Yamagata (2008). The "slope homogeneity test estimates indicate the selection of model".

$$\widehat{\Delta}_{ad} = \sqrt{N} \left(N^{-1} \widehat{H} - \frac{l}{SE(T,l)} \right) \sim N(0,1) \quad (23)$$

3.5.7. "Dynamic Common Correlated Effects (DCCE) Estimation Test"

The empirical literature, in the light of slope heterogeneity estimates suggested to opt the novel model developed by (Chudik & Pesaran, 2015), known as DCCE (henceforth, Dynamic Common Correlated Effects). Estimates of the DCCE model are significant for the dynamic panel and incorporates the problems covered in the "CCE methodology (Chudik & Pesaran, 2015) further modified by (Ditzen, 2018) for the for the short and long run heterogeneous panel estimation results in the panel".

Statistics of the model are developed rendered in the suitable rational approach, "the main aim of this model were to identify the founding nexus of variables in G20 countries" for greenhouse gas emission hypothesis by taking greenhouse gases as ecological footprint a dependent variable, and UNP, REC and OR as our independent variables. This chapter of thesis

adopted the crucial variables as they are the main variable of the research problem, meanwhile a latest advancement in the literature of oil rent and its binding relation with GHG emission promoted to adopt for analysis.

Statistics of the model "DCCE can be written on behalf of the model" specifications:

$$Y_{it} = a_i Y_{it-1} + \delta_i X_{it} + \sum_{p=0}^{PT} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{PT} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (24)$$

Where Y_{it} represent as dependent variable (LnGHG) and lag is denoted by Y_{it-1} , and X_{it} "denotes the independent variable, subscripts I and t show cross-sectional and time dimensions. The common unobserved factors are expressed by γ_{xip} and γ_{yip} and PT and μ_{it} shows the lag of cross-sectional averages and the error term".

$$LnGHG_{it} = a_i LnGHG_{it-1} + \delta_i X_{it} + \sum_{p=0}^{pT} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{pT} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (25)$$

The above equation, $a_i GHG_{it-1}$ is "the log of ecological footprint (greenhouse gas emission) used as the dependent variables, $\delta_i X_{it}$ indicates the set of independent variables like UNP, REC, and OR are reported by the X_{it} ".

3.6. Empirical Estimates

This section of the thesis, elaborate on the empirical findings and discuss in the previous literature findings. This section first conducted the CD test among the panel to identify the suitable panel unit test for the variables. This research considers "the empirical results of bias-corrected scaled LM test". Though, we also have considered the "Breusch-Pagan LM, Pesaran scaled LM, and Pesaran CD" tests. Based on the empirical results suggestion, CD in the panel examined. Therefore, this research conducts a second-generation panel unit-root test known as CIPS test. Meanwhile, this research also reported the "first-generation panel unit root IPS test estimates to enrich the research". Also, chapter also follows "Pedroni (1999) and Westerlund (2007) cointegration", followed by Slope Homogeneity test. Finally, to estimate the long-run coefficients of the model, the chapter follows Dynamic Common Correlated Effects method.

3.6.1. "Cross-Section Dependence Test"

The "table below shows the estimates of Cross-Section Dependence Test". The "Pesaran-CD, the Pesaran-scaled LM, and the Bias-corrected scaled LM statistics all showed that there exists the cross-section dependence in the panel data series of the taken variables". Moreover, the Pesaran-CD, the Pesaran-scaled LM, and the Breusch-Pagan LM statistics showed the cross-section dependence in the model as well. The all estimates are statistically significant at 1% level, indicating that the empirical study must rely on second generation panel data analysis.

Table 16. Cross-Section Dependence Test

Variable	Pesaran-CD		Pesaran-scaled LM		Bias-corrected scaled LM	
	Stat.	p-value	Stat.	p-value	Stat.	p-value
LnGHG	9.84	0.00*	145.25	0.00	144.89	0.00
REC	5.04	0.00*	115.71	0.00	115.35	0.00
UNP	3.76	0.00*	39.62	0.00	39.26	0.00
OR	41.85	0.00*	97.82	0.00	97.46	0.00
					Breusch-Pagan LM	
Model	5.69	0.00	98.50	0.00	2110.26	0.00

The "p-values confirm that there is a cross-section dependence between the variables and the model". Therefore, we adopt second generation panel data analysis to estimate our model.

3.6.2. Panel Unit Root Tests

From the table below, we can see that all the test statistics, the "IPL, CIPS, and CADF show that all the variables are differenced stationary". The CIPS statistics show that LnGHG, REC, UNP, and OR are differenced stationary at 1% statistical significance. Thus, "we conclude

that all the variables are differenced stationary, and we can look for long-run cointegration between the variables".

Table 17. IPS, CIPS, and CADF Unit Root Tests

Variables	IPS		CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LnGHG	-1.06	-4.87*	-2.16***	-4.70*	-1.99	-2.08**
REC	-0.27	-4.87*	-1.28	-4.81*	-1.18	-3.69*
UNP	-1.37	-3.79*	-1.63	-3.34*	-1.63	-3.34*
OR	-1.06	-8.05*	-1.72	-5.40*	-1.72	-4.43*

All the unit roots test indicates that all the variables are differenced stationary at 1 percent significance level.

3.6.3. Cointegration Test

This chapters considers the estimates of both, the first generation Pedroni cointegration and "the second generation Westerlund cointegration test, to check the presence of long-run association between the greenhouse gas emissions and renewable energy consumption, unemployment rate, and oil rents of G-20 countries between 1991-2019 period".

3.6.4. Pedroni (1999) Test for Cointegration

From the table below, we can see that Pedroni (1999) statistics indicate that there exist long run cointegration between the variables. Also, the estimates are statistically significant at 5% and 10% level of significance.

Table 18. Pedroni (1999) Test for Cointegration

	Statistic	p-value
Modified Phillips-Perron t	1.87	0.03
Phillips-Perron t	-1.84	0.03
Augmented Dickey-Fuller t	-1.42	0.07

3.6.5. Westerlund (2007) Cointegration Test

Moreover, all the p-values of the Westerlund statistics such as Gt, Ga, Pt, and Pa suggest that there exists a long run co-integration among all the variables at 1 percent significance level. These results check and verify both the first and second generation cointegration test. Therefore, it strengthens our claim that all the variables are cointegrated in the long run.

Table 19. Westerlund (2007) Cointegration Test.

Statistics	Value	z-value	p-value
Gt	-3.36	-8.70	0.00
Ga	-11.04	-2.78	0.00
Pt	-17.93	-8.27	0.00
Pa	-11.09	-5.81	0.00

3.6.6. Slope Homogeneity Test

Developed by (Pesaran & Yagamata, 2008), "the null hypothesis of this test is that slope coefficients are homogenous". In case, if "the null hypothesis is rejected, and the slope coefficients are found to be heterogenous". The novel DCCE method is adopted to estimate the long-run coefficients of the model.

Table 20. Slope Homogeneity Test

H0: Slope coef. homogenous	Delta	p-value
	-5.92	0.00
Adj.	-6.83	0.00

The p-values indicate that the null hypothesis of homogenous slope coefficients is rejected at 1 percent significance level. Therefore, it is concluded that the slope coefficients are heterogenous in nature, and we must adopt DCCE method since along with cross-section dependence and structural breaks problem, it covers the slope heterogeneity problem as well.

3.6.7. DCCE Model Estimates

The novel Dynamic Common Correlated Effects estimated results of our econometric model for overall G-20 countries, are presented in the table down below. The value of lags for the dependent variables (LnGHG) in this thesis research models is associated significantly with their explanatory variables (UNP, REC, and OR). Taking into consideration of diagnostic issues of the model, the Cross-Sectional dependency test confirms that the series experience "cross-sectional dependence while the homogeneity test confirms the heterogeneity of the slope coefficients". Thus, the DCCE method gives the reliable estimates of coefficient for our model.

In coming paragraph based on the empirical findings of the DCCE model are as shown below.

Table 21. DCCE- Pooled Mean Group & Mean Group Estimates

	Pooled Mean Group		Mean Group	
	Coef.	p-value	Coef.	p-value
D.LnGHG				
L.LnGHG	-1.14	0.04	-1.24	0.00
UNP	-0.01	0.00	-0.01	0.05
REC	-0.02	0.00	-0.02	0.00
OR	0.01	0.02	0.04	0.03
Constant	-4.89	0.12	-0.24	0.24

Note: *, ** and *** demonstrate the level of significance at 1%, 5% and 10%, respectively

Mean Group Variables: L.LnGHG, UNP, REC, OR

Cross Sectional Averaged Variables: D.LnGHG, L.LnGHG, UNP, REC, OR

The empirical findings of the novel DCCE model through both, PMG and MG methods show statistically significant coefficients. From the table above it can be observed that unemployment rate is positively related to greenhouse gas emissions, meaning that with increase in unemployment rate (lesser economic activities) greenhouse gas emission is increasing which

is an indication of the violation of EPC hypothesis. We can see, with 1% rise in unemployment rate the greenhouse gas emissions is falling by 0.01% at 1% and 5% level of significance through PMG and MG methods respectively. These estimates are consistent with the findings of (Tanveer et al., 2022) and shows that EPC is valid in G-20 countries.

Also, the DCCE estimation table shows that renewable energy consumption and greenhouse gas emissions is negatively related. We can see that with 1% rise in renewable energy consumption greenhouse gas emissions is falling by 0.02% with statistical significance of 1%, confirming our 2nd hypothesis of this chapter. These estimates are consistent with the findings of (Mansah et al, 2018).

Moreover, oil rents have found to be positively related with greenhouse gas emissions. The PMG estimate show that with 1% rise in oil rents, the greenhouse gas emissions rise by 0.01% with statistical significance of 5%. Whereas the MG estimates show that with 1% rise in oil rents, the greenhouse gas emissions rise by 0.04% with statistical significance of 5%. Both the estimates show statistically significant and positive coefficients, cancelling the third hypothesis of this chapter.

3.7. Conclusion

This chapter of the thesis aims at establishing the relationship and finding the long run estimates between the dependent variables i.e., "greenhouse gas emissions (LnGHG) and the explanatory variables such as, unemployment rate (UNP), renewable energy consumption (REC), and the oil rents (OR), in G-20 countries during the 1991-2019 period". The empirical estimates found that the panel data series of all the variables and the model has cross-section dependence and hence, along with first generation empirical techniques, the second-generation panel data analysis was adopted. Panel unit roots test statistics like, "IPS, CIPS, and CADF suggested that all the variables are differenced stationary, which indicated that long run cointegration exists among the variables". Therefore, "Pedroni (1999) and Westerlund (2007) cointegration tests" showed that there is a long-run association between the dependent variables i.e., the "greenhouse gas emissions (LnGHG) and the explanatory variables such as, unemployment rate (UNP), renewable energy consumption (REC), and the oil rents (OR), in G-

20 countries". Moreover, the slope homogeneity test indicated that the slope coefficients of the model are heterogenous. Thus, the adoption of DCCE method was prioritized, since it covers, the cross-section dependence problem, the structural break problem, as well as the slope coefficient heterogeneity problem. The DCCE method found that for G-20 countries between 1991-2019 time-period, the greenhouse gas emission is negatively related to unemployment rate, validating the Environmental Phillips Curve (EPC) hypothesis. Also, the "greenhouse gas emission is found to be negatively related to renewable energy consumption accepting the second hypothesis of this chapter", thereby, indicating that adoption of renewable energy consuming technologies is reducing the level of greenhouse gas emissions. Moreover, interestingly the oil rents and greenhouse gas emissions are found to be positively related in G-20 countries in the considered time-period, violating the third hypothesis of this chapter.

4. THE NEXUS BETWEEN GFCF, ENVIRONMENTAL TAX AND AIR POLLUTION EFFECTS IN EU-16 COUNTRIES.

4.1. Introduction

The natural consequences of the increasing economic activities that led to the adoption and imposition of the environmentally responsible economic growth policies were always the constantly shifting climate and the rising level of global competitiveness. These policy objectives motivate scientists to research and employ the most efficient use of resources throughout production to reduce environmental effects. Recent developments in "the literature show the consequences of environmental taxes on economic growth and investment spending", taking into account the effects of air pollution as well. The results of "the study on the negative impacts of air pollution on the environment advised that no economy's economic development should be kept a secret". The development of these nations' economy is mostly being driven by their investment spending. The "nexus of gross fixed capital formation is defined by the adoption of various technologies".

Due to its potential and improved coordination to reduce the issue of carbon emission, recent advancements in the literature of environmental policy and tax policy have attracted the attention of economists and policy makers. (Goulder & Parry, 2020, p, 152-174). In order to determine whether GDP and ET have had any appreciable effects on the degree of air pollution effects and the complementing phenomenon of GFCF among the 16 chosen countries of the European Union, this study focuses on potential solutions to this problem. The problematic usage of ET across the EU has been made simpler by the voluntary targets set by EU members over the past ten years for the reduction of air pollution and advancement in GFCF. The fundamental idea behind environmental taxes is that they serve as a tool for achieving long-term environmental objectives. The primary issue and cause of environmental pollution is when the parties that polluted did not have to bear any financial responsibility for their activities. Since the outset, conventional practices have been utilized to battle and maintain the standard emission level, including regulatory mechanisms with implications for policies (Popp et al, 2010, p. 873-937).

The 16 developed nations of European Union that make up GDP of EU are the subject of this study, and they are not the exception in that respect. In order to achieve the goals of green reform policies, a suitable utilization of gross fixed capital formation should be required.

The EU has set a goal to reduce the GHG emission to 40% by 2030 and around 80-90% in 2050 (Com, 2011; EU, 2014). The first step in the direction of sustainable economic development is to properly channel future investment. As evidenced by the developed economies' declining EKC curve, environmental tax programs are more effective in developed nations. The continued unchecked production demand and supply chain in developing countries, in sectors that appear to be economically inefficient, is the reason environmental tax policy functions better in developed countries. Taxes are uniform for all businesses, which causes the difference in marginal cost with no further technological innovation in pollution technologies. (Innovar, 2015, p. 65-80). Thus, it acts as a hindrance in the economic development of developing countries.

Environmental taxes have a significant impact on how new technologies are adopted and how fixed capital creation is channeled in industrialized nations with both uniformity and economic efficiency in the industrial and service sectors. According to the recommendations of environmental policy experts, taxing the energy-inefficient and non-renewable energy-consuming companies and services is urgently needed. In conclusion, strict taxation measures must be implemented in industrialized nations to discourage environmentally harmful activity. The effects of air pollution also appear to be rising steadily in terms of human health and geographic damage, on the other side. In order to actively avoid the deliberate effort of environmental damage, it is also necessary to evaluate the impacts of investment spending on air pollution. Additionally, these tools are quite beneficial and offer long-term support in the form of incentives, tax breaks, and primarily technological innovation and pollution reduction. (Li & Sun, 2015, p.34-60).

In sum, this chapter of the thesis is considering investigating the impact of economic growth (real GDP), environmental tax (Etax), and air-pollution effects (APE) on the gross fixed capital formation (GFCF) or the future expenditures.

4.2. Theoretical Background and Literature Review

This section of this chapter provides the theoretical background related with environmental tax, air-pollution, and economic growth in general. Moreover, this section will also describe the previous rigorous research works in this field.

4.2.1. Theoretical Framework

Here, we give a summary of the conceptual framework that will be applied to the development of the econometric model and that is crucial in determining which variables to use for this investigation. Environmental taxes have been shown to be an effective policymaking criterion for "reducing greenhouse gas emissions". (Gaith & Epplin, 2017), (Bashir et. al, 2020). Environmental tax changes have been found to negatively affect CO₂ emissions. (Sundar et. al, 2017), as "carbon emissions are the main cause of greenhouse gas emissions" (Hammar & Sjostrom, 2011). While several research (Meng et. al, 2013), (Jiang & Shao, 2017) and (Chen et. al, 2017) have shown how effective environmental taxes are, others like (Li & Lin, 2011) have suggested that "ET only have a small impact on greenhouse gas emissions".

Miceikiene et. al. (2018) when technical innovation in "the energy and environmental sectors is prioritized, environmental taxes are most successful at improving environmental quality, according to research on the subject". Studies on "the connection between environmental technology and carbon dioxide emissions are becoming more prevalent and can be broadly divided into two areas.: 1) how environmental technology helps in carbon emissions reduction and 2) how it supports cleaner sources of energy".

According to (Sun et al, 2008), who looked at "the effect of environmental patents on carbon dioxide emissions, innovation in environmental technology considerably reduces carbon emissions". Yang & Li (2017) suggested that "environmental technologies reduce carbon emissions because the positive impact of environmental advances in technical sectors reduces environmental contamination". They used China as their case study. By assessing the advancement of environmental technology.

By analyzing Mediterranean economies from 1990 to 2016, (Kahouli, 2018) "concluded that there is a negative correlation between technological development investments and carbon dioxide emissions". The conclusion "that environmental technology advancements are preventing environmental degradation is supported by the fact that the analyzed nations have vigorously promoted R&D investment in green technology to reduce greenhouse gas emissions. In their examination of the circumstances in the United States, China, and the European Union (Fernandez et al., 2018) claimed that while R&D funding in the US and EU was crucial for lowering carbon emissions, China's economy" would suffer as a result. Additionally, according to these writers, spending on environmental technology and investments can realistically help to lower carbon emissions. The fundamental economic objective remains the achievement of a set growth rate, making GDP growth one of the crucial macroeconomic indicators in the creation of a country's strategy. However, it is impossible to disregard the effects of environmental deterioration. As a result, in recent years, policymakers and academics have been interested in the relationship between future investments growth; gross fixed capital formation with environmental taxation as a major tool to curb the environmental degradation.

Based on "the literature review above and the theoretical framework, we can descriptively, write our model to evaluate the long run association between gross investments or gross fixed capital formation (GFCF) as a function of economic growth (GDP), environmental tax (ET) and air pollution effect (APE)" in the following manner.

$$GFCF = f(GDP, ET, APE) \quad (26)$$

Where, GFCF is our dependent variable, whereas GDP, ET, and APE are our explanatory or independent variables.

The important explanatory variables taken for our model are discussed below:

4.2.2. Environmental Taxes

The recent development in the EU environmental tax revenue comes from energy sector 77.2%, transportation 19.1% and portion of "taxes on pollution and resources is only 3.75, which

very small in comparison to other tax revenue represent 2.2% of EU GDP and 5.4% of total EU governments' revenue from taxes contributions (World Bank, 2020).

Pigou (1920) claims that "the ideal environmental tax is one that strikes a balance between the marginal private benefit of emissions in production and the marginal social damage of emissions". Environmental taxes are defined by international organizations as "a tax whose tax base is a physical unit (or a proxy of it) that has a proven specific negative impact on the environment" (United Nations, 2003). The United Nations definition, which is endorsed by the major international organizations including the OECD and the Statistical Office of the European Union, served as the foundation for the measure of environmental tax income used in this study (Eurostat). In the OECD's statistics on environmental taxes, taxes on energy goods such as fossil fuels, electricity, and transportation fuel are included (petrol and diesel). All CO₂-related taxes are included in this. The data on environmental tax income also includes motor vehicle and transport taxes, which include one-time import or sales taxes on transportation equipment, ongoing taxes on the ownership, registration, or use of motor vehicles on public roadways, as well as other transport-related taxes (excluding transport fuel taxes).

In 2016, the OECD has added more details regarding four different types of environmental tax revenue. These include "(i) taxes on ozone-depleting substances like dichloromethane and nitrogen oxides (CFCs); (ii) taxes on water and wastewater like those on water extraction, piped water, and wastewater treatment; (iii) taxes on waste management like those on the final disposal of solid waste and on packaging (like plastic bags); and (iv) taxes on mining and quarrying like mining royalties and excavation taxes (e.g., sand and gravel)". Other taxes were used to classify the remaining environmental tax revenue, which includes taxes on hunting, fishing, SO₂ emissions, and NO₂ emissions (Hassan et al, 2020). Thus, We used the total revenue from all environmental taxes as a proportion of GDP, which was derived from the OECD database, to analyze the relationship between environmental taxes and the pace of economic growth and the impacts of air pollution.

4.2.3. Air Pollution Effects

According to the OECD, breathing in "tiny particulate matter (PM_{2.5}) can cause major health problems, including respiratory and cardiovascular disease, and is particularly risky for children and the elderly". It has been established that exposure to PM_{2.5} greatly increases the risk of heart disease, including stroke. Premature death costs are the only costs included in cost forecasts. The "Value of a Statistical Life" (VSL) and the quantity of premature deaths related to ambient particulate matter are established and employed to determine the effects of air pollution.

The main issues brought on by air pollution are the dramatic changes in climate, acidification, eutrophication, urban air quality, decreasing level of ozone, quality of human development index, rising mortality rate, physiological changes in the human body, and rising death rate. Which of the century's oldest social and environmental issues has had devastating results the other way around. The rise of the industrial revolution and urbanization are primarily blamed for the degree of air pollution (Ortiz et al, 2020). The two primary types of pollutants that humans put into the air are anthropogenic and naturogenic due to the intricacy of air pollution. Due to the periodic change and association effects among the pollutants, identifying air pollution is challenging (Mauderly et al, 2009).

"GHG emissions, Ammonia (NH₃), Nitrogen Oxide (NO_x), Carbon Emission (CO₂), Particulate Matter (PM), Sulfur Dioxide (SO₂), Ozone, and Non-methane Volatile Organic Compound are the main pollutants defined by the European Union (NMVOCs)". Since the 1980s, every contaminant has been subject to stringent scrutiny. Numerous laws and legislative initiatives have been established to address pollutants that affect ambient air quality, primarily in the European Union, which is leading the world's group of nations in reducing greenhouse gas emissions from 15% to 8%. (Ortiz et al, 2020). The European Union has a total share of GFCF of 22% of total GDP for a green environment and to reduce emissions for good air quality with the total environmental tax revenue of 5.4% of GDP, only 72% of which comes from the energy sector, and the total GDP of EU member countries is approximately 23.4 trillion USD, making it the largest economy in the world (World Bank, 2021).

4.3. Literature Review

The preliminary research focusing on the behavior of environmental taxes regarding gross domestic product and industrial based air pollution effect globally, (Hassan et al, 2020) conducted research on 31-OECD countries using Correlation Random Effect (henceforth; CRE) a panel data approach over a period of 1994-2013. Their empirical findings indicated ET in high income level countries is increasing the initial level of GDP whereas the in countries with lower income level, the "GDP is negatively related to ET, both in long and in short run". Thus, "environmental taxes hypothesis is valid for high GDP level countries", in case of under-developed or developing countries ET can lead to shrink the economic growth due to the rise in price with increase in manufacturing and emissions. Moreover, the concept of ET is valid in those countries where service sector is more dominated than manufacturing sector due to the binding benefit of human capital in economic growth (Aloi & Tournemaine, 2011; Pautrel, 2009).

Safi et al, (2021) conducted research conducted on G7 countries validating the hypothesis of environmental taxes policy, over a period of 1990-2019. A panel data approach is employed which is known as "Cross-sectional Autoregressive Distribution Lag (Henceforth: CS-ARDL) with Common Correlated Effect Mean Group model (Henceforth: CCEMG)" by using variables, environmental related taxes, export, environmental-related R&D and consumption-based emission. Moreover, "the study also uses Granger Causality Test to check the direction of causation". The findings of this study validated the policy considering environmental related taxes with selected variables can significantly promote the reduction of carbon emission. Thus, it was denoted that the policy focusing on the promotion of environmental related tax could be the changing factor in developed countries as they do not have the problem of fluctuating economic growth due to their high level of human capital and concerns about the environmental quality.

Ghazouani et al. (2021) investigate the impact of ET and technologies on greenhouse emission in European countries over a period of 1994-2018. Fundamental estimation of the research covered under FMOLS & DOLS model. A panel data of greenhouse gas emission, environmental tax rate, renewable energy consumption, unemployment rate, and per capital gross domestic product growth rate was taken from world bank, OECD, and EIA. The empirical

research has found the presence of "cross-section dependence in the panel data of all the variables". Also, the second-generation unit root test found all variables are differenced stationary. Moreover, the second generation cointegration tests indicated that variables are cointegrated in the long run. Generalized least square regression empirical estimates found that ET and REC have a negative relationship with greenhouse gas emissions. Statistically, 1% rise in ET and REC can decrease in greenhouse gas emission up to 0.146% and 0.11% respectively. Furthermore, both FMOLS & DOLS model estimated coefficients are found to be statistically significant which posited that ET and environmental quality overall are an effective tool to decrease carbon emission. Suggestion of the research directed towards effective policies of environmental taxes and renewable energy consumption, sustainable jobs can help in unemployment and sustainable development.

Bashir et al. (2020) conducted research on OECD countries over a period of 1995-2015 to empirically investigate the relationship between "ET and carbon emission with role of environmental technologies and FD by adopting the pool OLS and GMM and regression approaches". Data of the research variables, CO₂, renewable energy, economic growth, ET, development of the technology, and financial development were obtained from the OECD. The empirical estimates of GMM model indicated that ET and RE has a significant negative relationship with carbon emission in OECD countries for long run, FD has a negative relationship with CO₂, ET considered to improve the environmental quality and level of human capital. Furthermore, OLS estimates outcomes indicated that economic growth has significant positive relationship with CO₂, ET and CO₂ significant negative relationship, where environmental technologies improve the environmental quality with significant negative value, financial development positive impact on emission improves the environmental quality results of the model were stable and significant. Thus, concluded that the technological innovations with investment can promote the sustainable economic development, considering the environmental quality and human capital can be improved through financial development and GFCF.

Degirmenci & Aydin (2021) investigated empirical research on several African countries over a period of 1994-2017, where panel data approach was analyzed by using AMG model. The "cross-section dependence and first difference stationarity were determined and the long

run cointegration between the variables was found". The empirical result of model explained that ET is negatively affecting CO₂ emission in long-run, meaning that with imposing of environmental taxes carbon emission is decreasing. The stability of the model was statistically significant. Hence, their suggestion directed the concern of the policy maker towards the control of degradation other than financial advancement in under developing countries as taken in the study are reliable. Also, as per the researcher suggestion, the environmental tax policies might be beneficial for developed and developing countries but under developing countries might face rise in unemployment and anthropogenic emission.

Niu et al. (2018) applied Bayesian dynamic approach to investigate the ET shock on CO₂ emission on China by employing "dynamic Stochastic general equilibrium (henceforth, DSGE) model". Estimation result indicated that ET has a negative effect in CO₂ reduction in China and can improve the energy intensity through consumption of renewable energy.

Abdullah & Morley (2014) research on "the nexus between environmental taxes and economics growth EU-25 and OECD countries for the period of 1995- 2006". They used a panel data approach for the variables, ET, GDP, tax on GDP, Ttax, ANS, DTax, GTax, RE by employing general approach of Granger non-causality test. Their Generalized method of moments (henceforth; GMM) method estimates indicated a long-term causality among the GDP and environmental taxes are positively related in EU-25 and OECD countries. Thus, the direction of the research pointed out towards the adoption of other variables and data. Therefore, it can be considered that the area and policy regarding ET and GDP needs to be advance by adopting the recent and latest explanatory variables to get the significant estimates. Subsequently, due to the lack of long data for China and USA indicates the significant estimates of the study. Capital formation in developed or developing countries might play an effective role in enhancing the environmental tax policies in improving the environmental quality.

Hashmi & Alam, (2019) conducted research on the role of environmental-friendly patent and taxes in promoting the sustainable green innovation and regulations in 29-OECD countries for the period of 1990-2014. A panel data approach was employed by using STIRPART, Fixed effect and GMM model empirical estimates for the variables, CO₂, total population, GDP, NEP, and ET were employed. The empirical model outcome indicated that number of environmental patents is negative and significantly related to the carbon emission, GDP and POP is positively

related to carbon emission. Thus, it was denoted that the collection of ET and environmental development are considered to be responsible for the better environmental quality in economic development.

Nchege & Okpalaoka (2022) conducted research to identify the relationship among GFCF and air pollution in Nigeria by employing the ARDL model approach for the year of 1985-2019. Empirical estimates of the research found the significant and positive relationship of air pollution with GFCF and GDP. Thus, increase in air pollution could be the outcome of growing economy with can be tackled by the adoption of environmental taxes and revenue spent in the direction of sustainable development goals.

Mujtaba & Shahzad, (2021) research on the implication of sustainable development policies in OECD countries over a period of 2002-2018 by employing a panel data empirical technique by adopting variables (Health, GDP, CO₂, nitrogen oxide as air pollutant, education, and renewable energy) and FM-OLS and VECM model approach to estimate the coefficients. Empirical estimates of the research outlined that advancement of sustainable investment is negatively and significantly related to the air pollution, which can be denoted as adoption of sustainable investment policy can reduce the rising problem of pollution with the positive relation to economic growth. Therefore, GFCG in developed and developing economies is appearing as an effecting agent to combat the rising problem of air pollution and sustainable GDP.

He et al, (2021) "analyzed the heterogenous impact of environmental taxes on energy efficiency in OECD countries for the period of 1995-2016". The functional criteria of the research aimed to identify the impact of various taxes on energy efficiency with economic growth by employing panel ARDL model approach. The empirical estimates of the research indicated that energy efficiency is significantly related to the environmental taxes for long and short run in the OECD countries, which is significantly helping the condition of environment. Moreover, estimates of the ARDL panel approach also pointed out that the functional size of GDP does matter for environmental tax impact in energy efficiency and level of emission by adopting renewable energy. Thus, the research led us to explore the impact of environmental taxes on developed countries by following the different approach and latest explanatory variables.

Li et al, (2021) conducted research to check the impact of environmental tax impact on air pollution in China's plant over a period of 2017-2019. also found the positive relationships among environmental taxes and air pollution, which impacted positively on emission reduction in China. Also, GFCF in case of China is negatively related to air pollution effects (Khan et al, 2021).

Shahzad, (2020) conducted a theoretical survey "based on the previous literature findings". The researcher pointed out on the three functional criteria from theoretical perspective in the light of previous literature. In this study, environmental taxes, environmental quality, and energy consumption were considered the main explanatory linkage in emerging, developed, or underdeveloped economies where the literature considered in the research was up to the year 2020. The concluding remarks indicated the adoption of renewable energy consumption policies in an economy which has high energy intensity, to reduce the rising problem of air pollution and green economic development and adoption of environmental taxes and subsidies to promote the implication of sustainable policies, can lead to sustainable environment. Thus, it can be said that initially GFCF and ET could lead to shrink the economy in developing and underdeveloped countries due to the size of the GDP and level of human capital index. However, for developing nations ET related policies can show positive impacts from the beginning itself.

Table 22. Summary of the Literature Review

Authors	Country	Period	Variables	Methodology	Conclusion
Hassan et al. (2012)	31-OECD	1994-2013	GDP, ET, TLF, LAED, EXP, Tax, FB, GFS, INF, CPI, OPENG	CRE	ET is Positively related to GDP in developed Economies
Safi et al. (2021)	G-7 Countries	1990-2019	ETs, Export, ER&D, CCE,	CSARDL, CCEMG	ET is Positively related to GDP, GFCF is Positively related to the environmental quality
Ghazouani et al. (2021)	EU	1994-2018	GHG, ET, RE, UNP, GDPC,	FMOLS, DOLS,	Negative relationship between ET and overall pollution

Bashir et al. (2020)	OECD	1995-2015	ET, EC, REC, ET, CO2, ETax, FD, DT	OLS, GMM	Negative ET with GDP Positive FD is Positively related with GDP, Environmental Quality
Degirmenci & Aydin (2021)	5 African Countries	1994-2017	CO2, UNP, ET,	AMG	Negative Relationship ET and economic growth, Positive FD, Environmental Quality,
Niu et al. (2018)	China	EPT law adopted in 2016	Bayesian E-E-E	DSGE	ET has a negative relationship with CO2 which helps improve in APE.
Abdullah & Morley (2014)	25-EU, OECD	1995-2006	GDP, ET, DTax, GTax, RE, ANS	ARDL, EPC,	ET positively related to GDP
Hashmi & Alam (2019)	29-OECD	1990-2014	CO2, GDP, POP, NEP, ET	GMM	ET positively related to GDP
Nchege & Okpalaoka (2022)	Nigeria	1985-2019	APE, GDP, GFCF, CO2,	ARDL	GFCF positively related to GDP
Mujtaba & Shahzad (2021)	28-OECD	2002-2018	Health, GDP, CO2, AP, EDU, RE,	FMOLS, VECM	AP is negatively related with CO2
He et al. (2021)	OECD	1995-2016	Energy Tax, VT, Environmental Tax, EI, GDP, FDI,	ARDL	ET is positively related with GDP and FDI
Li et al. (2021)	China	2017-2019	Heat, Tax rate, Air pollution, Environmental Pollution	---	Tax is negatively related with Air Pollution

4.3.1. An Overview of the Literature Review

The issues of gross domestic product, gross capital formation, and environmental taxation have all been the subject of much literature investigation. However, more needs to be learned about the effects of air pollution. In previous literatures, environmental pollution employed as a proxy for the effects of air pollution (see Mujtaba & Shahzad, 2021). This chapter has considered GFCF, GDP, ET and APE variables for the research, previous prominent literature around the theme of ET and GDP nexus found significant negative relationships with GDP, the other hand GFCF considered as constructing agent for the GDP, air pollution and environmental pollution significantly found to be the positive factor in the reduction of environmental degradation with the substantial environmental taxes. In light of the literature which social scientists have found to be extremely essential, this chapter of the thesis considers GFCG, ET, and APE as key players in the economies to prevent environmental degradation.

4.4. Data and the Model

In this thesis section, the type of the data of our variables and their sources is described. The panel data of the "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects" is constructed by taking the timeseries data of 16 European countries (Henceforth: EU-16) which are as; "Austria, Belgium, France, Finland, Germany, Iceland, Ireland, Italy, Japan, Netherlands, New Zealand, Norway, Poland, Spain, Sweden, and UK".

4.4.1. Data Source

The annual panel data, which were collected from 1994 to 2020, were utilized to analyze the data in this study. Type of data collection is annual basis. The data is mainly obtained from primary source i.e., (OECD, 2022) to avoid disability of the model and to draw the appropriate results. The main source of all the data type is OECD website of open database. The data of "Gross fixed capital formulation Growth and the Gross Domestic Product at constant price (Real GDP in \$) and Air Pollution Effects" is taken in natural Logarithm to avoid the variability and

maintain the smoothness of the data. The data of the Environmental Tax is taken in percentage terms as the percentage of GDP.

Table 23. Data Source & Description

Variables	Description	Unit	Form	Source
LnGFCF	Gross fixed capital formulation Growth	Level	Natural Logarithm	OECD
LnGDP	Real gross domestic product growth rate	Level	Natural Logarithm	OECD
Etax	Environmental Tax Rate	% Of GDP	-	OECD
LnAPE	Air Pollution Effects	Level	Natural Logarithm	OECD

*Source: OECD open data base.

4.4.2. Correlation Matrix

Correlation Matrix shows the coefficient of correlation between the variables of our model. The coefficient of correlation ranges between +1 and -1. From the table below, we can see that LnGFCF shows high positive correlation with LnGDP, meaning that "gross fixed capital formation and gross domestic product are highly correlated". Also, LnGFCF shows negative correlation with environmental tax (Etax) and positive correlation with air pollution effects (LnAPE).

Table 24. Correlation Matrix

Variables	LnGFCF	LnGDP	Etax	LnAPE
LnGFCF	1.00	0.99	-0.20	0.50
LnGDP	0.99	1.00	-0.17	0.52
Etax	-0.20	-0.17	1.00	0.27
LnAPE	0.50	0.52	0.27	1.00

4.4.3. Descriptive Statistics

The table below shows the description of several statistics of our variables of European Countries taken into study at a glance.

Table 25. Descriptive Statistics of the Variables

Descriptive Statistics	LnGFCF	LnGDP	Etax	LnAPE
Obs.	432	432	432	432
Max.	14.12	15.49	3.74	6.89
Min.	7.01	8.74	0.98	3.80
Mean	11.60	13.13	2.42	5.50
Std. Dev.	1.49	1.49	0.59	0.73
Skewness	-0.76	-0.72	0.07	-0.43
Kurtosis	3.63	3.43	2.56	2.38
Jarque - Bera	48.91	41.32	3.82	20.45
J-B Prob.	0.00	0.00	0.09	0.00

The data of all the variables of these European Countries has 432 number of observations. The "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects" data is centered over 11.60, 13.13, 2.42, and 5.50 percent respectively.

The statistic standard deviation which measures the spread or the dispersion of the dataset of "gross fixed capital formation, gross domestic product, environmental taxes, and air pollution effects", in relation to its mean is 1.49, 1.49, 0.59, and 0.73 respectively.

The skewness is a statistic which measures the presence of asymmetry in the distribution of the dataset around its mean. For a normally distributed series, the value of skewness is zero. Therefore, the positive/negative value of skewness suggests "that there is long tail in the right/left side of the distribution". Environmental taxes have a tail on the right side of the distribution, whereas gross fixed capital formation, gross domestic product, and air pollution effects exhibit long tails on the left.

The kurtosis is a statistic which measures the presence of peaked-ness or the flatness of the distribution of the series. For a normally distributed series the value of Kurtosis statistic is 3. Therefore, the estimated Kurtosis values of all the variables shown above indicates the presence of peaks.

After estimating that the distribution has skewness as well as peak, it is indicated that the series distribution is normal. The Jarque-Bera probability confirms the presence of normal distribution in all the dataset from 1994 to 2020.

Following (Karmekar et al., 2021), we can write our empirical model in the following manner.

$$LnGFCF = a_0 + \alpha_{1i} LnGDP_{it} + a_{2i} Etax_{it} + a_{3i} LnAPE_{it} + \varepsilon_{i,t} \quad (27)$$

Based on the empirical equation above our hypothesis of this chapter are as follows:

Hypothesis 1: Gross Fixed Capital Formation and Gross Domestic Product are positively related i.e., $\alpha_{1i} > 0$.

Hypothesis 2: Gross Fixed Capital Formation and Environmental Tax are negatively related i.e., $\alpha_{2i} < 0$.

Hypothesis 3: Gross Fixed Capital Formation and Air Pollution Effects are positively related i.e., $\alpha_{3i} > 0$.

4.4.4. Justification of Hypothesis and Variables

These hypotheses are based on the theoretical framework, previous literature reviews, and several environmental economic theories. For example, first hypothesis is simply based on the macroeconomic principle that, “improvement in rate of economic growth can cause a substantial rise in investment or gross fixed capital formation” (Pettinger, 2019 economicshelp.org). Also, the second hypothesis follows the EKC hypothesis in a sense that, as per the literature review, economic growth and carbon emissions are positively related, meaning major economic activities are causing carbon emissions. Therefore, to curb the carbon emissions, if the environmental tax policies are levied on those economic activities, then it will reduce the future investment spendings. Hence, principally the environmental tax and gross fixed capital formation must be negatively related. Moreover, the third hypothesis again follows the positive (EKC) type relationship of economic growth and carbon emissions. Since, carbon emissions are causing serious socio-economic problems, for example, health, mortality rate, and life expectancy. Therefore, there must be "a positive linkage between gross fixed capital formation and air pollution effects, since investment spendings are done at the cost of environment, human-life, and humanity".

4.4.5. Panel Data Plots of the Variables of the Model

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. Below we discuss the panel data plot of gross fixed capital formation, gross domestic product, environmental tax, and air-pollution effects in the EU-16 countries from 1994-2020.

4.4.6. Panel Data Plots of the Gross Fixed Capital Formation

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The gross fixed capital formation rate of EU-16 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see Japan has been leading in gross fixed capital formation followed by Germany in the EU-16 group countries. Overall, almost all the EU-16 countries have been experiencing significantly positive growth rate in gross fixed capital formation.

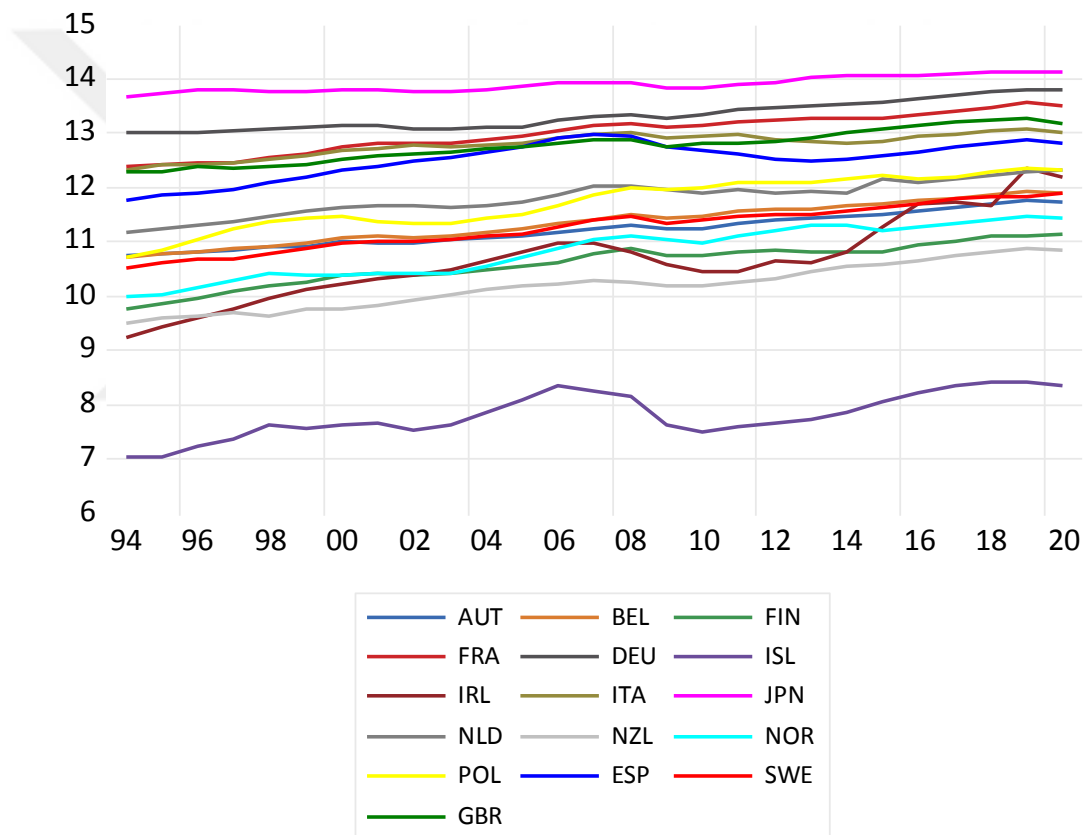


Figure 9. Panel Data Plots of the Gross Fixed Capital Formation

4.4.7. Panel Data Plots of the Gross Domestic Product

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The gross domestic product rate of EU-16 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see Japan has been leading in gross fixed capital formation followed by

Germany in the EU-16 group countries. Overall, almost all the EU-16 countries have been experiencing significantly positive growth rate in real GDP.

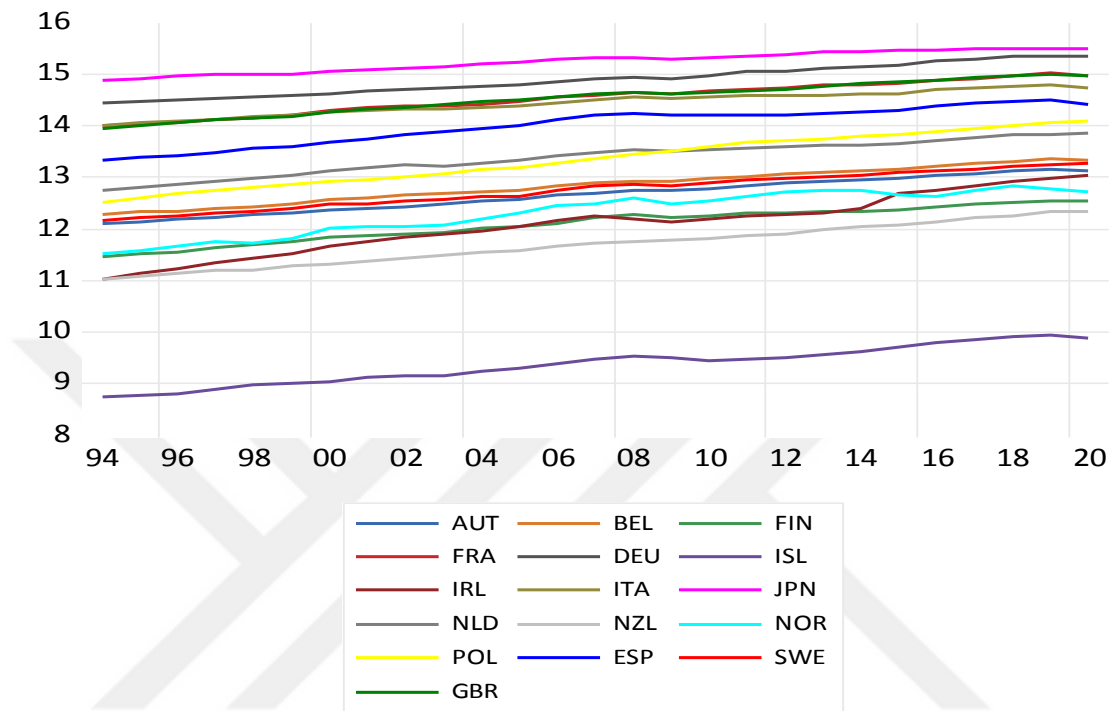


Figure 10. Panel Data Plots of the Gross Domestic Product

4.4.8. Panel Data Plots of the Air Pollution Effects

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The air-pollution effects rate of EU-16 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see Poland has been leading in air-pollution effects followed by Italy in the EU-16 group countries. Overall, almost all the EU-16 countries have been experiencing significantly positive effects of air-pollution. Therefore, taking this variable into account while framing the econometric model is a reliable step.

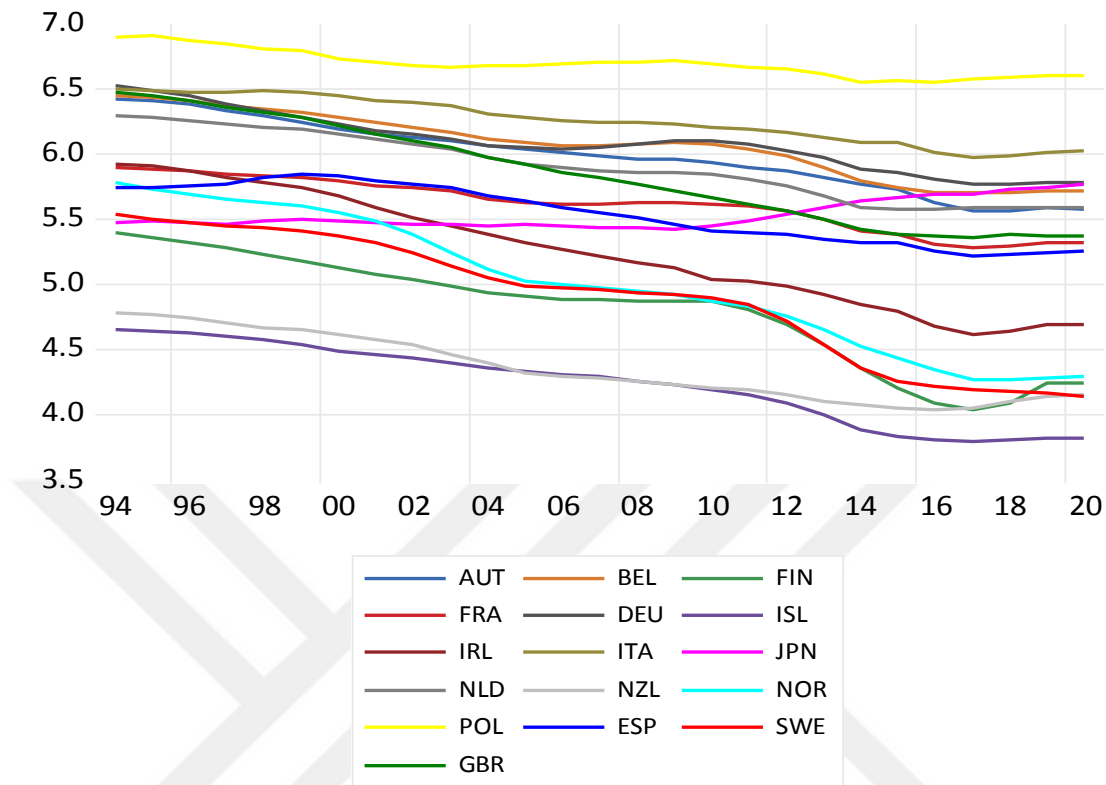


Figure 11. Panel Data Plots of the Air Pollution Effects

4.4.9. Panel Data Plots of the Environmental Tax

Panel data plots bestows the visual illustration of the data from which the trend, seasonality, structural breaks in the series can be visually witnessed. The environmental tax rate of EU-16 countries through the panel data plot from 1991-2020 can be seen below. From the graph we can see Germany has been leading in imposing environmental taxes followed by Italy in the EU-16 group countries. Overall, almost all the EU-16 countries have been imposing environmental tax in the range of 1% - 4%.

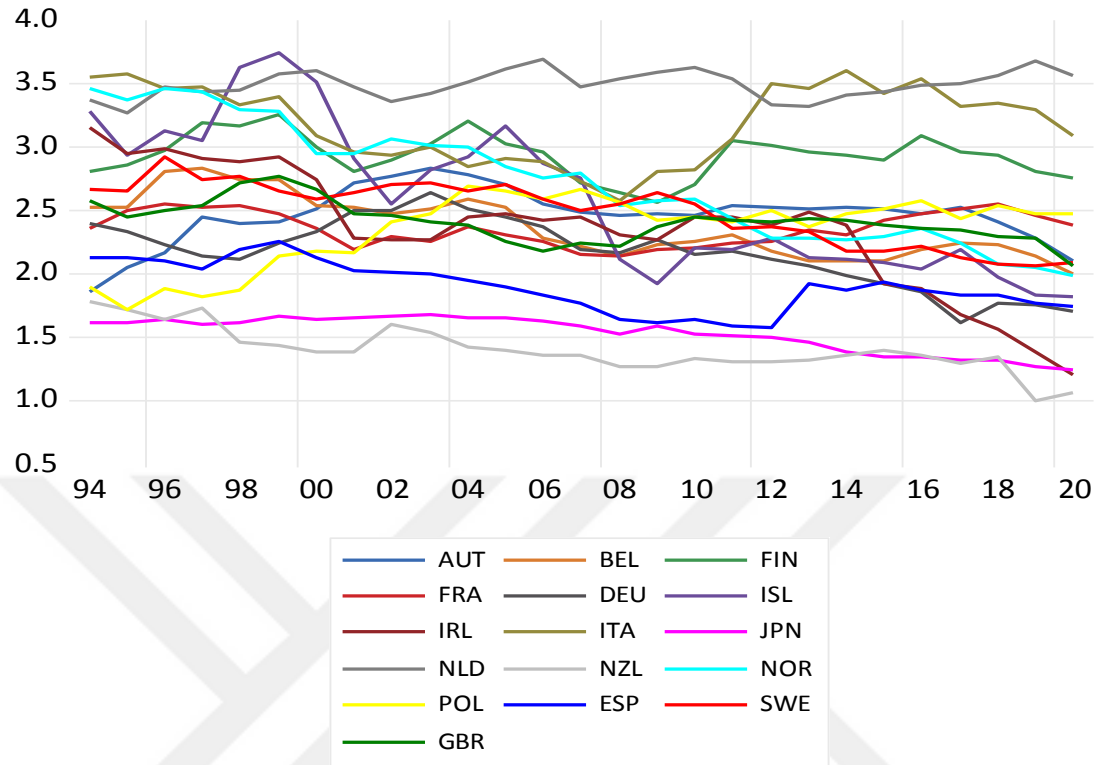


Figure 12. Panel Data Plots of the Environmental Tax

4.5. Methodology

A second-generation panel data approach was used in this thesis for EU-16 countries. We have adopted the advanced panel data techniques in these studies described in subsections. Cross-section dependence test, first and second generations panel unit root test, first and second generations panel cointegration test, and lastly the innovative dynamic common correlated effects to estimate the coefficients followed by homogeneity test make up the remaining steps of the thesis.

4.5.1. Cross-sectional Dependence Test

Thesis has conducted many series of tests to analyze "the presence of cross-sectional dependence (henceforth, CDS) in the panel like CD test, Lagrange multiple (henceforth, LM) test, the scaled-LM test, and the adjusted scaled-LM test". The homogeneous procedure of the LM test proposed by Breusch, and Pagan (Breusch & Pagan, 1980). CD_{LM1} can be used when

the panel is relatively larger than the cross-section dimension (N) and the CD_{LM2} was developed by (Pesaran, 2004) can be used. For further details follow the previous chapter. The bias-adjusted LM test is framed stepwise down below in the following manner.

$$LM_{LM1} = T \sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \quad (28)$$

In equation (1) $\widehat{P}_{ij}^2$ represent the sample estimate of the pairwise correlation coefficient. (Pesaran, 2004) proposed further a scaled version of the LM test.

$$Scaled\ LM\ Test = \sqrt{\left(\frac{1}{N(N-1)}\right)} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N (T \widehat{P}_{ij}^2 - 1) \right] \quad (29)$$

The "scaled LM test demonstrate significant size misrepresentations in the case of $N > T$ " (Pesaran, 2004). Therefore, (Pesaran, 2004) prepared alternative test for "CD, which is applicable in the case of $N > T$ or $T < N$ ".

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \left[\sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \right] \quad (30)$$

The "CD test consists of multiple breaks in slope coefficients and postulate robust results for the heterogeneous dynamic panel data". (Baltagi et al. 2012) adjusted CD test method by adding accurate variance and mean of the LM statistics.

$$CD = \sqrt{\left(\frac{2T}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N \widehat{P}_{ij}^2 \frac{(T-k)\widehat{P}_{ij}^2 - \mu_{T\ ij}}{\sqrt{v_{T\ ij}^2}} \quad (31)$$

In the above equation $v_{T\ ij}^2$ and $\mu_{T\ ij}$ represents the rigorous discrepancy of standard deviation and mean of $(T - k)\widehat{P}_{ij}^2$ which was categorized by the research (Baltagi et al. 2012). Table LMadj Test Results introduces cross-sectional dependence results of the variables and cointegration equations used in this thesis section from CD_{adj} test. Different test (CD, scaled LM, LM-adjusted) are employed to verify the CDS between cross-sectional unit. The outcome of these CDS tests is helpful to decide the appropriate estimate methodology.

Which is Known as Bias-corrected scaled LM test can be described are as follows:

$$\text{Bias - corrected Scaled LM} = \sqrt{\left(\frac{1}{N(N-1)}\right) \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T_{ij} \widehat{P}_{ij}^2 - 1)} - \frac{N}{2(T-1)} \quad (32)$$

So, in case if the cross-section dependency is found in the series, the second-generation panel unit root test must be used.

4.5.2. IPS Panel Unit Root Test

First-generation and Second-generation panel unit root tests analysis are included in the literature on linear panel unit root tests. For further details follow the previous chapter. The "IPS panel unit root test statistics $\widehat{t}$ " needs to be acquired from Augmented Dickey-fuller (ADF)" test by taking its average:

$$\bar{t} = \frac{1}{N} \sum_{i=1}^N t_{pi} \quad (33)$$

where, t_{pi} represents the individuals t -statistics. The IPS test null hypothesis claims that in "each series of the panel have a unit root" (Im et al., 2003; Baltagi, 2008).

4.5.3. CIPS Panel Unit Root Test

The second-generation panel unit root test knows as CIPS (henceforth, Cross-sectionally Augmented IPS). For further details follow the previous chapter. Also, The mean of the CADF test estimates refers to the CIPS test which is as follows:

$$\text{CADF} = t(N, T) = \frac{\Delta y_i^t \bar{M}_i y_{i-1}}{(\Delta y_{i-1}^t \bar{M}_i y_{i-1})^{1/2}} \quad (34)$$

which is transformed into CIPS by averaging it as described below.

$$\text{CIPS} = N^{-1} \sum_{i=1}^n t(N, T) \quad (35)$$

4.5.4. Panel Cointegration Test

This study used Pedroni (1999) and Westerlund (2007) ECM panel cointegration tests to examine the existence of cointegration among the variables CO2, GDP, and GFCF. The null

hypothesis is no cointegration among the panel and alternate hypothesis is cointegration present among the panel. In order to determine whether there is a long-run convergence among the variables, we performed a panel cointegration test of the first and second generations in this work. First, we used Pedroni's (2004) first-generation test, and then Westerlund's (2007) second-generation cointegration test, which is often used in theses. (Westerlund, 2007) test is more accurate as it takes into consideration all of the above-mentioned issues such as heteroskedasticity, CDS, and serial correlation. This test authorizes the co-integration or long-run association among variables and interpret outcomes well with small data/or structural breaks (Westerlund, 2007). This test used panel-based statistics (panel Γ and panel α) and group mean-based statistics (panel Γ and panel α). Panel-based statistics calculate the error-correction term of the whole panel, on the other hand, group mean-based statistics regress the weighted mean for the error-correction term. Therefore, these test statistics analyses the long-run association among relationships among the selected variables through the means of error correction for the whole panel as well as individual cross-sections.

4.5.4.1. "First Generation Cointegration Test Pedroni (1999)"

This study first used the first-generation panel cointegration test developed by Pedroni (2004), to examine the existence of relationships among the panel. This test examines the seven different statistics referred to as within and between dimensions. The tests null hypothesis examines the cointegration present among the panel meanwhile, alternate hypothesis examines the cointegration present among the panel. Following equation indicates the Pedroni, (2004) cointegration test are as follows:

$$Y_{it} = \alpha_{it} + \delta_i t + \gamma_{2i} E_{it} + \gamma_{2i} L_{it} + \gamma_{3i} K_{it} + \varepsilon_{it} \quad (36)$$

In the above given equation, $i=1,.. N$ for individual countries in the panel and $t=1,..T$, indicates the time period. The factors α_{it} and δ_i permit the possibility of country-specific fixed effects and determined trends, respectively. ε_{it} denote the deviations in the residual estimates in long-run relationships. All variables are demonstrated in natural logarithms, the γ_s indicates the model elasticities. Based on residual of (Engel & Granger, 1987) cointegration regression,

(Pedroni, 1999 & 2004) proposed different number of statistics, to test the null hypothesis of no cointegration in the heterogenous panel.

4.5.4.2. "Second Generation Cointegration Test Westerlund (2007)"

This error-correction model of panel second-generation cointegration test is developed by Westerlund (2007), which is used to examine the null hypothesis of no cointegration. For further details follow the first chapter methodology section. Following equation represents the Westerlund (2007) are as follows:

$$\begin{aligned} \Delta \text{LnGFCF}_{2,it} = & \alpha_i^c + \lambda_i^c (\text{LnGFCF}_{2,it-1} - \beta_i^c \text{LnGDP}_{2,it-1} - \gamma_i^c \text{Etax}_{i,t-1} - \\ & \lambda_i^c \text{LnAPE}_{i,t-1}) + \sum_{j=1}^m \theta_{i,j}^c \Delta \text{LnGFCF}_{2,it-j} + \sum_{j=1}^n \delta_{i,j}^c \Delta \text{LnGDP}_{it-j} + \sum_{j=1}^p \phi_{i,j}^c \Delta \text{Etax}_{i,t-j} + \\ & \sum_{j=1}^o \lambda_{i,j}^c \Delta \text{LnAPE}_{i,t-j} + \mu_{i,t} \end{aligned} \quad (37)$$

4.5.6. Slope Heterogeneity Test

This test is used to check slope heterogeneity presence in the model and to investigate and identify the optimal selection of estimated model. For further details follow the first chapter methodology section. A test Statistics are as follows:

$$\widehat{\Delta} = \sqrt{N} \left(N^{-1} \widehat{H} - \frac{1}{2l} \right) \sim X^2_l \quad (H)$$

$$\widehat{\Delta}_{ad} = \sqrt{N} \left(N^{-1} \widehat{H} - \frac{l}{SE(T,l)} \right) \sim N(0,1) \quad (SE)$$

A larger sized sample (whole data set) is estimated through Eq. (H), whereas small sample-sized samples (ER sample, CR sample, and WR sample) are estimated in the Eq (SE).

4.5.7. Dynamic Common Correlated Effects (DCCE) Estimation Test

The Dynamic Common Correlated Effects (henceforth, DCCE) methodology, which was recently created by Chudik and Pesaran (2015), was used in this study to elaborate on the CD issue that was not addressed in prior models that provide biased estimates. Previous research asserted that the development era's economic forces and unknown shocks led to the emergence

of CD. This method's key justification was that it forecasts the variables as common components and attributes the CD to unnamed and unseen sources. which were mostly based on the mean group (MG) estimation, pooled mean group (PMG) estimation, and common correlated effects (CCE), which were developed for the first time by (Pesaran & Smith, 1995 & 2006) respectively. The primary issues with this recently established approach are that it is appropriate for dynamic panels and takes into account the issues with the CCE methodology. Adding to the above remarks, the DCCE method of (Chudik & Pesaran, 2015) was further expanded by (Ditzen, 2018) for the heterogeneous panel estimating outcomes for both short- and long-term estimations. As a result, it was inevitable that the DCCE approach would address a number of important issues, many of which were either disregarded or went unnoticed in the previous methodologies, as was evident from the results of many studies. The model addresses the problem of (i) heterogeneity, (ii) it integrates the dynamic common correlated effects by using common factors, (iii) it deals with the issue of heterogeneity problems, (iv) the main consideration could be taken into account as it is applicable for the case of sample size, and (v) the main consideration was realistic (Ditzen, 2016).

The primary goal of this model was to identify the causes of variables on each other in BRIC countries for carbon emission by using carbon emission as a dependent variable and GDP and GFCF as our independent variables. The model's specifications were elaborated in a pragmatic manner that was appropriate.

The following mentioned equation of DCCE can be written on behalf of the model specifications:

$$Y_{it} = \alpha_i Y_{it-1} + \delta_i X_{it} + \sum_{p=0}^{PT} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{PT} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (38)$$

The dependent variable and its lag are included in the equation above are Y_{it} represent as dependent variable while its lag is denoted by Y_{it-1} , and X_{it} represents the independent variable, cross-sectional and time dimensions are indicated by the subscripts i and t . "The common unobserved factors are expressed by γ_{xip} and γ_{yip} and PT and μ_{it} shows the lag of cross-sectional averages and the error term". We have further extended into our variables for providing the "Carbon emission (Pollution heaven BRIC countries) hypothesis by combining the ecological footprint as dependent variable (Carbon emission)".

$$LnGFCF_{2,it} = a_i LnGFCF_{2,it-1} + \delta_i X_{it} + \sum_{p=0}^{p^T} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{p^T} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (39)$$

The above equation, $a_i LnGFCF_{2,it-1}$ is the log of gross fixed capital formation used as the dependent variables, $\delta_i X_{it}$ indicates the set of independent variables like LnGDP, Etax, and LnAPE are reported by the X_{it} .

4.6. Empirical Estimates

The test statistics and statistical estimates for our empirical model are provided in the following sequence in this section. The Cross-Section Dependence testing estimates are presented first. Second, we use the IPS, CIPS, and CADF unit roots tests to examine stationarity based on the results of the CD test. Thirdly, using the Pedroni and Westerlund test, we check for the existence of long run cointegration after validating the difference stationarity of all the variables. Following the discovery of long-run cointegration, we use the Dynamic Common Correlated Effects technique to estimate the long-run coefficients. We do the homogeneity test before calculating the coefficient to determine whether or not each unique coefficient is homogeneous or heterogeneous.

4.6.1. Cross Section Dependence Test

Several estimating strategies can be used to examine cross section dependence. The cross-section dependence test is provided by a number of statistical approaches, including the Pesaran-CD, Pesaran-Scaled LM, and Bias Corrected Scaled LM. All test data in the table below display significant values. The p-values demonstrate that the variables are cross-sectionally dependent. The Breusch-Pagan LM statistics indicated that the model contained cross-section dependence. Therefore, we use second-generation panel data analysis to estimate our model in order to solve the cross-section dependence issue.

Table 26. Cross Section Dependence Test

Variable	Pesaran-CD		Pesaran-scaled LM		Bias-corrected scaled LM	
	Stat.	p-value	Stat.	p-value	Stat.	p-value
LnGFCF	51.79	0.00*	166.62	0.00*	166.31	0.00*
LnGDP	56.19	0.00*	196.11	0.00*	195.80	0.00*
Etax	13.50	0.00*	50.06	0.00*	49.75	0.00*
LnAPE	42.45	0.00*	177.28	0.00*	176.97	0.00*
					Breusch-Pagan LM	
Model	10.06	0.00*	28.52	0.00*	561.95	0.00*

4.6.2. Panel Unit Root Tests

Depending on the CD tests, different strategies can be used to determine whether there are unit roots in a panel of data for a certain variable. We apply the IPS unit root test if the data do not exhibit any cross-sectional dependence; otherwise, we employ the CIPS and CADF test statistics. All of the variables are differenced stationary, as can be seen in the table below. The statistically significant values are provided by the IPS, CIPS, and CADF test statistics. At the 1% level of significance, the LnGFCF, LnGDP, Etax, and LnAPE are differenced stationary, indicating that the long run cointegration of the variables can now be examined.

Table 27. IPS, CIPS, and CADF Unit Root Tests

Variables	IPS		CIPS		CADF	
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)
LnGFCF	-1.17	3.67*	-1.92	-3.82	-1.92	-3.82*
LnGDP	-1.60	-3.82*	-1.67	-4.07*	-1.67	-4.07*
Etax	-1.14	-4.75*	-1.77	-4.88*	-1.90	-3.05*
LnAPE	-0.75	-2.12*	-0.94	-2.51*	-1.92	-2.36*

4.6.3. Pedroni (1999) Test for cointegration

Pedroni (1999) is the best test method to determine whether there is long run cointegration between the variables when there is no cross-sectional dependence in the dataset. According to the table below, there is a long-term cointegration between the variables according to the Phillips-Perron t-stat, Augmented Dickey-Fuller t-stat, and Modified Phillips-Perron t-stat. At the 5% and 10% significance levels, each test statistic is statistically significant.

Table 28. Pedroni (1999) Test for Cointegration

	Statistic	p-value
Modified Phillips-Perron t	1.25	0.09
Phillips-Perron t	-1.55	0.05
Augmented Dickey-Fuller t	-1.49	0.05

4.6.4. Westerlund (2007) Cointegration Test

The Westerlund (2007) test is preferable when cross-section reliance exists in the data set because it solves the cross-section dependence issue. Four descriptive statistics were supplied

by the cointegration test by Westerlund (2007): Gt, Ga, Pt, and Pa. We can see from the table below that the majority of the statistics point to long-term cointegration between the variables used in our analysis. It is statistically significant to use the estimated statistics. As a result, at a 1 percent level of significance, all the p-values indicate that there is a long-term co-integration between all the variables.

Table 29. Westerlund (2007) Cointegration Test

Statistics	Value	z-value	p-value
Gt	-2.29	-2.29	0.01
Ga	-7.36	0.28	0.61
Pt	-9.79	-3.45	0.00
Pa	-7.78	-2.22	0.01

4.6.5. Slope Heterogeneity Test

Developed by (Pesaran & Yagamata, 2008), this test checks the homogeneity of the individual slope coefficients of the model. The null hypothesis of this test is that the slope coefficients are homogenous. However, the table below shows that the null hypothesis is rejected at 1 percent level indicating that the slope coefficients are heterogenous. This result raises the problem of heterogeneity and therefore, to overcome that, we must adopt the novel Dynamic Common Correlated Effects to estimate the coefficients of our empirical model.

Table 30. Slope Heterogeneity Test

H0: Slope coef. homogenous	Delta	p-value
	18.94	0.00
Adj.	20.98	0.00

The p-values indicates that the null hypothesis of homogenous slope coefficients is rejected at 1 percent significance level

4.6.6. Dynamic Common Correlated Effects

Dynamic Common Correlated Effects is a novel method, which is the key estimation technique of the second-generation panel data analysis. The DCCE method, overcomes, the cross-section dependence problem of the data modeled, structural breaks in the data arising from market and non-market fluctuations, and the problem of heterogeneity in the individual coefficients. Since, our data has cross-section dependence problem, and the individual coefficients are found to be heterogenous. This is the most appropriate method to estimate the long-run coefficients of our empirical model. The table below shows coefficients statistics in two different categories. The Pooled Mean Group and the Mean Group coefficient statistics. Both these categories show slightly different estimates.

Gross fixed capital formation and economic growth have a statistically significant positive association, according to the DCCE: PMG figures. The coefficient of LnGDP is 0.91 which is statistically significant at 1 percent level indicates that, with 1 percent increase in GDP in EU-16 countries, the gross fixed capital formation increases by 0.91 percent. Moreover, the DCCE: MG statistics also shows that there is a positive linkage between LnGDP and LnGFCF of EU-16 countries. However, the coefficient of LnGDP is 0.66 which is statistically significant at 5 percent level indicated that with 1 percent rise in LnGDP the LnGFCF rises by 0.66 percent. In conclusion we say both these coefficients are statistically significant and are consistent with the (Pettinger, 2019) and accepts our first hypothesis.

Also, the DCCE: PMG estimates found LnGFCF to be positively related with the air pollution effects. The coefficient of LnAPE is 0.30 which is statistically significant at 10 percent level indicates that with 1 percent rise in air pollution effects, the gross fixed capital formation rises by 0.30 percent. However, the DCCE:MG statistics also show that LnAPE and LnGFCF to be positively related. The coefficient of LnAPE is 0.15, which is statistically significant at the 5% level showed that the GFCF increases by 0.15 percent for every 1 percent increase in LnAPE. Thus, in conclusion, these estimated coefficient of LnAPE is consistent with the

(Nchege & Okpalaoka, 2022) and (Mujtaba & Shahzad, 2021) and confirms our second hypothesis.

Moreover, the DCCE: PMG estimates found that environmental tax and gross fixed capital formation are negatively related. The coefficient of Etax is -0.03, which is statistically significant at 10 percent level indicates that with 1 percent rise in Etax, the LnGFCF falls by 0.03 percent. However, the DCCE:MG statistics also show that Etax and LnGFCF to be negatively related. The coefficient of Etax is -0.07, this is statistically significant at the 5% level and showed that the GFCF decreases by 0.07 percent for every 1 percent increase in Etax. Thus, in conclusion the established relationship and estimated coefficient is consistent with (Hassan et al, 2012), (Abdullah & Morley, 2014), and (Miceikiene et. al, 2018).

Table 31. DCCE- Pooled Mean Group & Mean Group Estimates

	Pooled Mean Group		Mean Group	
D.LnGFCF	Coef.	p-value	Coef.	p-value
L.LnGFCF	-0.72	0.00*	-0.49	0.00*
LnGDP	0.91	0.00*	0.66	0.03**
LnAPE	0.30	0.07***	0.15	0.04**
Etax	-0.03	0.09***	-0.07	0.05**
Const.	-0.95	0.71	2.49	1.00

4.7. Conclusion

This chapter of this thesis tries to establish the long run relationship between gross fixed capital formation as a dependent variable with our dependent variables such as, gross domestic product, air pollution effects, and environmental tax in EU-16 countries between 1994-2021 time-period by adopting second generation panel data analysis techniques. The research

questions or the hypothesis were, first, Gross Fixed Capital Formation and Gross Domestic Product are positively related, second, Gross Fixed Capital Formation and Air Pollution Effects are positively related, and third, Gross Fixed Capital Formation and Environmental Tax are negatively related. The Novel DCCE estimation technique was adopted to estimate the long-run coefficients. The empirical estimation part showed that all variables and the econometric model has cross-section dependence. Also, the second-generation unit roots test also confirmed differenced stationarity at 1 percent statistical significance. In addition, using panel cointegration tests, it was confirmed that all the variables are cointegrated in the long run. Moreover, slope homogeneity test confirmed that individuals slope coefficients are heterogenous. Finally, the adoption of novel DCCE method gave reliable estimates of the long-run coefficients. The DCCE estimates confirmed all the hypothesis. Firstly, long run cointegration and positive relationship between Gross Fixed Capital Formation and Gross Domestic Product was found. Second, it was discovered that Gross Fixed Capital Formation and the effects of air pollution have a positive association and long-term cointegration. Thirdly, long run cointegration and negative relationship between Gross Fixed Capital Formation and Environmental Tax was also obtained. Therefore, based on the estimated results we can conclude that, EU-16 countries are experiencing the high economic growth, due to investment spendings at the cost of environmental degradation since the air pollution effects are found to be positively related with gross fixed capital formation. However, at the same time, the negative relationship established between environmental tax and gross fixed capital formation shows that adoption of environmentally friendly policies such as environmental tax keeps the non-sustainable economic growth at check, and this is consistent with the policy recommendations of previous researchers mentioned in the literature review. Hence, we can say that the theoretical framework, the econometric model, and the empirical estimates provided the most consistent, novel, and reliable results.

5. CONCLUSION AND POLICY RECOMMENDATIONS

The thesis consists of three theoretically modelled and empirically estimated studies on environmental economics of the global economy in general and of BRICS-4 & USA, G-20, and EU-16 countries in particular. The first essay revisited the EKC hypothesis to check the impact of future investment spendings (GFCF) on carbon emissions using novel second-generation panel data approach in countries producing highest percentage of carbon emission in the world, like, Brazil, Russia, India, China, and USA. The second chapter revisited the EPC hypothesis to check the effect of unemployment rate on the greenhouse gas emissions of the G-20 countries by using the novel panel data analysis. The third chapter empirically investigated the impact of air pollution effects and Environmental Taxation on the gross fixed capital formation of the EU-16 countries.

The empirical estimates of the first essay indicated that gross fixed capital formation is increasing the carbon emission in BRICS-4 countries and USA meaning that, GFCF and CE are positively related. As a result, our initial hypothesis—that GFCF and CE have a beneficial long-term relationship—is confirmed. However, it is discovered that the gross domestic product and carbon emissions are inversely correlated, supporting the second hypothesis from our first chapter. The acceptance of the first two hypothesis of this chapter eventually leads to the acceptance of the third hypothesis which results in the validation of EKC hypothesis in the BRICS-4 countries and USA.

Since GFCF is the component of expenditure on GDP and the validation of EKC hypothesis through positive relationship between GFCF and CE is an indication that investment spendings in these countries are playing major role in creating the carbon emission than the economic growth. Hence, based on these statistically significant empirical findings, we can put forward several policy recommendations for the experts. First, they must be careful while making future investments. Since GFCF is basically the investment spendings, therefore, policymakers must design policies in such a way that future investment spendings in done on environmentally friendly technologies and industries. Second, the GFCF can also be directed towards the sustainable development programs, such as adoption of renewable energy resources, production of efficient machineries, and raising awareness about environmental protection.

The estimations of the second essay demonstrated that rising unemployment rate is decreasing the greenhouse gas emissions in the G-20 countries, thereby, validating the EPC hypothesis. Also, the empirically estimated results indicate that renewable energy consumption is decreasing the greenhouse gas emissions in G-20 countries. Moreover, as found in the empirical results, the oil rents estimated to be positively related to the greenhouse gas emissions in G-20 countries. Thus, based on these empirically sound and reliable results we can make some policy recommendations for the environmental policymakers. First, it is interesting to know that in case of G-20 countries, a falling unemployment rate (increase in employment) is causing increase in greenhouse gas emissions. Therefore, policy makers must apply a more suitable pathway which is sustainable in the long term in a sense that environmental degradation must be ameliorated without affecting the employment opportunities for the increasing unemployed labor force in G-20 countries. In light of the second finding—that there is a link between the use of renewable energy and greenhouse gas emissions—policymakers should continue to fund technologies that use renewable energy while discouraging the use of non-renewable energy sources like coal and petroleum. Third, it has been discovered that oil rents are positively correlated with greenhouse gas emissions, indicating to policymakers that oil rents need to be regulated in order to reduce dependence on oil-consuming technology.

The third essay of this thesis empirically estimates the nexus between gross fixed capital formation, gross domestic product, air-pollution effects, and environmental tax in EU-16 countries. The findings showed that GDP and GFCF are positively related indicating that investment spendings depends on the size of the GDP. Also, air-pollution effects and GFCF are positively related indicating the validation of EKC hypothesis. Moreover, GFCF is found to be negatively related to environmental tax. Since all these findings are statistically significant. Therefore, reliable policy recommendations can be made. First, it is suggested that policy makers should design policies in a manner that protect the human resources. Since, human resources is the human-capital and is necessary for the economic development. Therefore, investment spendings must be regulated in health sector to protect the human life, increase life expectancy, and thereby decrease mortality rate as well. Second, use of cleaner and efficient form of energy must be increased. Third, policy makers must employ the environmental tax effectively in a sense it must not harm the overall economic growth rate. It must target only the sectors which are leading players in carbon emissions. The sectors which use non-renewable

energy sources must be taxed and to compensate for that government must provide subsidies to increase the adoption renewable energy dependent technologies.

In sum, this thesis supports the idea that the discussion of climate change in academic arena must be encouraged further. Through the findings the thesis posits that carbon emissions led economic growth is the fundamental problem all over the world. The policy suggestions such as adoption of more efficient energy, imposition of environmental taxes, investment spendings in health sector and environmental campaign programs, monitoring of oil rents, and managing rising unemployment without harming environment further must be the key priorities of the policymakers all over the world.

6. REFERENCES

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