



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

<sup>1</sup>Zeeshan Malik, <sup>2</sup>Osama Shaikh,

<sup>1</sup>Ph.D. Social Policy, Department of Social Policy, Yildirim Beyazit University, Turkey, 165215408@ybu.edu.tr,

<sup>1</sup>ORCID 0000-0003-1165-6147

<sup>2</sup>Phd Economics, Department of Economics, Hacettepe University, Turkey, <sup>2</sup>osama.shaikh@hacettepe.edu.tr

<sup>2</sup>ORCID 0000-0002-9873-8040

**Abstract:** This paper examines the effects of the unemployment rate, consumption of renewable energy, and oil rents on the annual greenhouse gas emission rate of G-20 countries from 1991 to 2020 by using second-generation panel data analysis. The primary goal is to examine the validation of Environmental Phillips Curve hypothesis in G-20 countries. According to the empirical estimations, all the variables are cross-sectionally dependent, differenced stationary, and cointegrated over the long run. Also, DCCE estimates found that the unemployment rate and greenhouse gas emissions are negatively related. Therefore, the EPC hypothesis is validated in G-20 countries. Moreover, findings also reveal that greenhouse gas emissions is negatively related to renewable energy consumption and positively related with oil rents, respectively.

**Keywords:** Environmental Phillips Curve, Greenhouse Gas Emissions, Unemployment Rate, and Second-Generation Panel Data Analysis

**JEL Code:** C51, Q01, Q53, Q52

## 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 et al, 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 (Shaikh, 2020). (Bhattacharyya, 2019; p331-363).

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 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.

## 2. Theoretical Framework & Background

This section of the study will elaborate on the theoretical background to analyze the nexus between three environmental indicators 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.

### 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 (Shaikh, 2021). According to Okun's law, as production declines in a positive way, unemployment and production in an economy are positively correlated (Lee, 2000). 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 based on 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.

### 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, p791-864). Considering 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. 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. 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-corelated 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 analyze 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 E., 2022) have suggested that in case of BRICS 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-corelated 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 analyzed 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 et al, (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 stationary 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 CO<sub>2</sub> 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, CO<sub>2</sub> 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 2003-2018 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 CO<sub>2</sub> 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 CO<sub>2</sub>, renewable energy, Fossil fuel energy, GDP, GDP<sub>2</sub>,

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 run for BRICS and OECD countries. Pairwise regression coefficient illustrated that an 1% increase in REC will improve CO<sub>2</sub> 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 CO<sub>2</sub> 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 1990-2014 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 CO<sub>2</sub> is negatively related to NREC, which means 1% increase in RE decreases up to 0.4497% by AMG, 0.5832% by CCEMG in CO<sub>2</sub> emission in long run. D-H panel "bidirectional causality indicated a bidirectional causality between CO<sub>2</sub> emission and renewable energy at global". Hence, "it was noted that renewable energy consumption has a significant negative impact on CO<sub>2</sub> 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 CO<sub>2</sub> emission in BRICS countries.

**Table 1.** Summary of Literature Review

| Authors                | Country               | Period    | Variables                                     | Methodology         | Conclusion                       |
|------------------------|-----------------------|-----------|---|---------------------|----------------------------------|
| Ng et al. (2022)       | OECD                  | 1995-2015 | EC, GDP, GDP <sup>2</sup> , CE, UNP,          | CCEMG, AMG, EKC EPC | EPC Valid                        |
| Liu & Feng (2022)      | 77 Countries          | 1991-2022 | CO <sub>2</sub> , 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<br>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,<br>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,<br>Positive relationship GDP and REC  |

### 3.1. 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 paper 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.

### 4. Data 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.

**Table 2.** 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)

#### 4.1. Corelation Matrix

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

**Table 3.** 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.

#### 4.2. Descriptive Statistics

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

**Table 4.** 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 |



|                      |       |        |         |         |
|----------------------|-------|--------|---------|---------|
| <b>Jarque - Bera</b> | 94.46 | 218.65 | 2084.55 | 9702.96 |
| <b>J-B Prob.</b>     | 0.00  | 0.00   | 0.00    | 0.00    |

Source: Authors Calculation

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

### 4.3. 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:

$$P = a + by \quad (1)$$

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".

$$u = c + dy \quad (2)$$

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.

$$p = e - gu \quad (3)$$

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).

$$GHG = f(UNP, REC, OR) \quad (4)$$

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:

$$LnGHG = a_0 + \alpha_{1i}UNP_{it} + \alpha_{2i}REC_{it} + \alpha_{3i}OR_{it} + \varepsilon_{i,t} \quad (5)$$

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.,  $\alpha_{3i} > 0$ .

### 4.4. 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.

## 5. Methodology

Updated and consistent econometric techniques advancing the research by using panel data approach, considering cross-section dependency. In this paper 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".

### 5.1. Cross-section Dependence in the Series

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".

$$Bias - corrected Scaled LM = \sqrt{\left(\frac{1}{N(N-1)}\right)} \sum_{i=1}^{N-1} \sum_{j=i+1}^N (T_{ij} \widehat{P}_{ij}^2 - 1) - \frac{N}{2(T-1)} \quad (6)$$

In case of CD in the series, a second-generation panel unit root tests should be used.

### 5.2. CIPS Panel Unit Root Test

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



$$CADF = t(N, T) = \frac{\Delta y_i^t \bar{M}_i y_{i-1}}{(\Delta y_{i-1}^t \bar{M}_i y_{i-1})^{1/2}} \quad (7)$$

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

$$CIPS = N^{-1} \sum_{i=1}^n t(N, T) \quad (8)$$

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.

### 5.3. Westerlund (2007) Panel Cointegration Test

This research adopted the cointegration test developed by Westerlund, (2007) which analyze "the error correction term group mean ( $G_\tau$  and  $G_\alpha$ ) and panel ( $P_\tau$  and  $P_\alpha$ ) is equal to zero in a panel error-correction model". The test statistics are obtained from Westerlund (2007) and modified as our model required:

$$\Delta GHG_{i,t} = \alpha_i^c + \lambda_i^c (GHG_{it-1} - REC_{it-1} - \beta_i^c UNP_{it-1} - \gamma_i^c OR_{it-1}) + \sum_{j=1}^m \theta_{i,j}^G \Delta GHG_{it-j} + \sum_{j=1}^n \delta_{i,j}^G \Delta UNP_{it-j} + \sum_{j=1}^p \phi_{i,j}^G \Delta REC_{it-j} + \sum_{j=1}^n \vartheta_{i,j}^G \Delta OR_{it-j} + \mu_{i,t} \quad (9)$$

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).

### 5.4. Slope Heterogeneity Test

The slope heterogeneity test developed by Pesaran & Yamagata (2008). The "slope homogeneity test estimates indicate the selection of model".

$$\hat{\Delta}_{ad} = \sqrt{N} \left( N^{-1} \hat{H} - \frac{l}{SE(T,l)} \right) \sim N(0,1) \quad (10)$$

### 5.5. 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 method.

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

$$LnGHG_{it} = a_i LnGHG_{it-1} + \delta_i X_{it} + \sum_{p=0}^{PT} \gamma_{xip} \overline{X_{t-p}} + \sum_{p=0}^{PT} \gamma_{yip} \overline{Y_{t-p}} + \mu_{it} \quad (11)$$

The above equation,  $a_i LnGHG_{it-1}$  is "the log of greenhouse gas emission used as the dependent variables,  $\delta_i X_{it}$  indicates the set of independent variables like UNP, REC, and OR.

## 6. Empirical Estimates

This section of the thesis, elaborate on the empirical findings and discuss in the previous literature findings. 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. Also, paper also follows Westerlund (2007) cointegration test, followed by slope homogeneity test. Finally, to estimate the long-run coefficients of the model, the paper follows Dynamic Common Correlated Effects method.

### 6.1. 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. The all estimates are statistically significant at 1% level, indicating that the empirical study must rely on second generation panel data analysis.

**Table 5.** 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    |

|              |       |       |       |      |                         |      |
|--------------|-------|-------|-------|------|-------------------------|------|
| <b>OR</b>    | 41.85 | 0.00* | 97.82 | 0.00 | 97.46                   | 0.00 |
|              |       |       |       |      | <b>Breusch-Pagan LM</b> |      |
| <b>Model</b> | 5.69  | 0.00  | 98.50 | 0.00 | 2110.26                 | 0.00 |

## 6.2. Panel Unit Root Tests

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 6.** IPS, CIPS, and CADF Unit Root Tests

| Variables    | CIPS     |        | CADF  |         |
|--------------|----------|--------|-------|---------|
|              | I(0)     | I(1)   | I(0)  | I(1)    |
| <b>LnGHG</b> | -2.16*** | -4.70* | -1.99 | -2.08** |
| <b>REC</b>   | -1.28    | -4.81* | -1.18 | -3.69*  |
| <b>UNP</b>   | -1.63    | -3.34* | -1.63 | -3.34*  |
| <b>OR</b>    | -1.72    | -5.40* | -1.72 | -4.43*  |

## 6.3. Westerlund (2007) Cointegration Test

This paper considers the estimates of 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". 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.

**Table 7.** 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    |

## 6.4. Slope Homogeneity Test

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.

**Table 8.** Slope Homogeneity Test

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

## 6.5. DCCE Model Estimates

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 9.** 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 2<sup>nd</sup> hypothesis of this paper. 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, rejecting the third hypothesis of this paper.

## 7. Conclusion

This paper 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 paper", 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 paper.

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