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THE ROLE OF RENEWABLE AND NONRENEWABLE ENERGY IN ECONOMIC DEVELOPMENT AND ENVIRONMENTAL DEGRADATION: EVIDENCE FROM G20 COUNTRIES

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Abstract
G20 countries are rapidly growing economies that face severe environmental problems due to their heavy dependence on energy consumption. Therefore, this study investigates the influence of renewable and non-renewable energy consumption on economic growth and environmental degradation in G20 nations. For this study, we scrutinized the panel data of G20 countries from 2010 to 2023. Based on PSCE and FGLS estimators, the study findings reveal that renewable energy consumption is significantly associated with economic growth and negatively associated with environmental degradation. Additionally, non-renewable energy consumption significantly impacts both economic growth and environmental degradation. These findings reveal that renewable energy consumption contributes to an eco-friendly environment, and non-renewable energy consumption contributes to environmental degradation. Hence, we encourage policymakers to promote investment in green energy projects to deal with environmental issues.

Keywords: Renewable energy consumption, economic growth, nonrenewable energy consumption, environmental degradation.

1. Introduction

In modern technology era, both developed and developing nations have common objective to achieve the economic growth with environmental sustainability. Nevertheless, countries growing economy leads to increase the production of goods and services and this need enhance energy demand. Energy sector serves as the backbone of each country and empower the country prosperity. Broadly energy sources are dividing into two type non-renewable energy and renewable energy (Hanif et al., 2019). Renewable energy obtains from the natural resources such as sunlight, wind, rain and geothermal heat. It is eco-friendly and renewal source of energy (kumar et al., 2019). In order to attain the sustainable growth, renewable energy is considered the best source and also known as green energy because it decreases the energy consumption via energy efficiency. Thus, it drives the economy to low emissions of carbon. Due to green energy demand Govt and policy maker turned his attention toward green energy investment that increase the production efficiency and decrease energy consumption as well as protect environment from hazards (Hussain et al., 2025; Li et al., 2022). Moreover, well structure financial system effectively allocates the resources which enhance the shift to a low carbon emission and promoting defendable environment (Appiah-Otoo et al., 2023). Renewable energy has significant relation with economic growth and play important role to boost the economy of country (Bélaïd and Youssef 2017; Armeanu et al. 2017) and also reduced the harmful impact of CO2 and protect environmental damage (Nathaniel and Iheonu 2019). Energy considered the vital input for economic development process as well as economic growth increases the living standard of people (Nam et al., 2024). Additionally, harmful impact of CO2 reduces by the use of renewable energy which improves the nation's growth and development. To address the increase global energy demand, economists explore

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the association between energy consumption and economic growth (Pegkas, 2019; Cevik et al, 2020).

In human history, industrial revolution recorded as the starting of new period described by growth and development. Non-renewable energy consumption increased day by day as the world's population and economy grow as well and its impact on environment also grows. Non renewable energy sources are the remains of ancient animal and plant such as fossil fuel. These resources are scare and also non-renewal (IEA, 2023). These resources damage the environment and change the climate condition, include coal, natural gas and oil (UNFCCC, 2015). Need of non-renewable energy increased in every country which enhanced the CO2 emission that causes environmental pollution (Güney, 2019). Because when fossil fuel burn, they evacuate residue like harmful gases and solid substance that can't be recycled (Dogan & Seker, 2016). Main culprit behind environmental degradation is CO2 emission originating from non-renewable energy sources. Particularly in the period of economic enlargement and globalization when economies are heavily depends on the energy sources and it considered vital factor in growth (Adil et al., 2025; Dansofo et al, 2024) Recently authors explore the positive association of the non-renewable energy with growth and positive with environmental degradation (Li et al., 2022; Shafiei & Salim, 2013). In 2023, 1.1% increase in the emission of CO2 from worldwide energy source attaining highest level of 37.4 billion tons up 410 million tonnes year to year (IEA, 2023). Vital factor behind this destruction is the excessive use of non-renewable energy sources to fuel economic growth (Cevik et al, 2020; Pegkas, 2019). The united nation has recognized energy consumption is the main issue of environmental damage that nearly 60% of global greenhouse gases outflows. This climate change encourages international co-operation to decrease CO2 emissions and support environment friendly energy consumption.

G20 countries are selected for our study due to its notable impact on energy, global economy and environment. G20 countries consist of world's biggest economy including both developed and developing nation. It shows approximately 80% of world trade, 60% of world population and 85% of economic gross domestic product (Appiah-Otoo et al., 2023). In order to resolved environmental issue G20 countries take action by shift toward the green technology, promoting sustainable practices and expand economic growth via eco-friendly polices (Adil et al., 2024; Uddin et al., 2022). G20 countries gradually increase their share in clean energy source, in 2023 41% of their electricity was generated from the less harmful energy source which protect environment from damage. But fossil fuel consumption also increases in these countries such as 59% electricity is generated by non-renewable energy source (Ember, 2024). However, G20 countries fossil fuel utilization has increased approximately 15.39%. In 2010 fossil fuel consumption is 92804TWH and rise to 107585TWH in 2023. United Kingdom has lowest fossil (-36%) consumption while India has highest consumption of fossil fuel (+67%) (Our world in data, 2024a).

Consumption of nonrenewable energy sources increased the CO2 level in environment that leads to raise global warming, sea level and harm ecosystem balance. Reason behind increase in level of CO2 is increased the uses of fossil fuels. Statistically 15% increase in CO2 by G20 countries from 2010 to 2023 which damage environment severely (our world in data, 2024b). Increase in emission of CO2 was led by with highest point India (83%) while United Kingdom achieved the reduction in CO2 emission have lowest point (-40%). This point show that excessive use of nonrenewable energy increases the emission of CO2 such as India same in the case of United Kingdom which use low amount of nonrenewable energy sources and emit less CO2. Nonrenewable energy sources boost the economic growth but also lead to environment degradation.

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United nation analyzed that the nonrenewable energy consumption is the major issue behind the emission of CO2 which damage the environment nearly emit 60% of global greenhouse gases outflow. Pair agreement in 2015 goal is to reduce the outflow of CO2 by adopting the renewable energy source and reduced the consumption of nonrenewable energy sources. Additionally, pair convention follows by 195 countries set a common goal to reduce global warming from 2^C to 1.5^C. by adopting renewable energy nations aim to achieved sustainable development by minimize the emission of CO2 and its harmful impact on environment (UNFCCC, 2015). Brazil has highest score (50.33%) in the use of renewable energy as well as Saudi Arabia have lowest score (0.47%). Use of renewable energy source upgrades environmental sustainability without damage the economic growth in Brazil. Investment in renewable energy with modern technology enhances the environment quality with economic growth.

Hence, goal of this study is added to the ongoing literature by exploring the impact of renewable energy on economic growth and environmental degradation as well as also add nonrenewable energy impact on economic growth and environmental degradation. We selected G20 nation data that are worlds growing economy and also worldwide technological forefront. There are few literatures that investigate the association of renewable energy, non-renewable energy, economic expansion and environmental degradation. However, we introduced the novelty in this literature by analyze both form of energy renewable and nonrenewable at a time. Our prime goal is to investigate which energy source has coupled effect, ecofriendly with economic expansion. Our motive is to fulfill the research gape by analyzing the impact of renewable and nonrenewable energy at the same time with economic development and environmental deterioration in G20 nations. Hence, we apply two econometric estimations, first is panel-corrected standard errors (PCSE) and second is feasible generalized least squares (FGLS). When there is cross-sectional dependence, serial correlation, and heteroskedasticity in the data these two approaches make strong estimations. With the help of the policy recommendation, G20 maintain sustainable environment with economic expansion worldwide.

2. Literature Review

Due to modern technology, world's energy demand level has put great impact on the consumption of renewable and non-renewable energy sources. In this modern era it is important to understand the effect of energy on growth and environment. However, research on energy sector is expanding but significant knowledge gape is exist relating to the comparative impact of renewable and non-renewable energy on economic growth and environmental degradation**.**

2.1 Renewable Energy Consumption and Economic Growth

Bąk et al. (2024) analyzed the impact of renewable energy consumption and production on economic growth in Poland. This study utilized the power econometrics model to identify the relationship between economic expansion and renewable energy consumption and production in the period from 2005 to 2022. Finding reveal that in Poland energy usage and its production increase and enhances the economic expansion of country which show that renewable energy consumption is a major source of energy for development of economies. Dirma et al. (2024) analyzed that renewable energy has significantly contribute to economic expansion because it increases the job creation and invest in renewable energy enhance the technological development, innovation and infrastructure. Various challenge also occurred in adopting the renewable energy but this plays important role in enhancing development in countries but also need to balance approach and planning. This study covers the period from 2000 to 2021. Study reveals that 1% increase in renewable energy consumption enhances the 0.00763% economic growth. Moreover, Weng (2024) discovered that in china's renewable energy consumption has significantly contribute to economic expansion in long run and also

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analyzed that governments polices is required to earn more benefits from renewable energy source. These regulations decrease the inhibitor effects problem and expand the growth of country. In conclusion renewable energy enhances the economic growth through direct and indirect effects. However, Mohamud and Mohamud (2023) evaluated that the renewable energy has substantial positive impact on economic growth, in short term outcome revealed significant positive nexus between oil price and renewable energy however have significant negative impact on FDI's, population and environmental degradation. Pairwise granger causality test and ARDL econometric tools were used and covered the study period from 1990 to 2020. Additionally, Kasperowicz et al. (2020) exposed the impact of renewable energy consumption on economic growth in 29 European countries from 1995 to 2016. Study analyzed that the renewable energy consumption has balanced relationship with economic growth. Economic growth and renewable energy consumption have significant positive association. Results also reveal that enhance the consumption of renewable energy reduces the greenhouse gas outflow and maintain sustainable environment.

Based on the discussion above, we hypothesize that:

H1: Renewable energy consumption has a significant and positive influence on economic growth.

2.2 Non-Renewable Energy Consumption and Economic Growth

Aghayeva (2024) scrutinized the influence of nonrenewable energy and renewable energy consumption on economic growth in Azerbaijan. Study period of this literature was 1990 to 2020. Finding reveal that the non-renewable energy consumption significantly contributes to economic development, 1% utilization of non-renewable resources enhance the 3.8% economic expansion. Study also reveals the significant positive association between growth and renewable energy consumption. Moreover, Behera et al. (2023) explore the significant positive relationship between economic growth and non-renewable energy consumption in India. India's growing economy heavy depends on energy satisfy their need. Results show strong relationship between economic expansion and non-renewable energy consumption. Furthermore, results also explain the positive relationship between economic development and renewable energy consumption. The data period of this study was 1985 to 2021 in India. Aswadi et al. (2023) explored the influence of energy consumption on economic development covering the study period from 1990 to 2019 in Indonesia. In this era energy sector is most important in building the country's economy. Results reveal that the Indonesia's economy is strongly depends on the usage of non-renewable energy consumption. Fossil fuel consumption is very high in country. Results show the positive relationship between economic growth and non-renewable energy consumption. However, Noor (2023) explored that economic growth is the main objective of South Asian countries. Energy sector is a vital source to fulfil this objective. For sustainable development, Authors examine the relationship of non-renewable energy consumption impact on growth. Finding show that non-renewable energy consumption enhances the country's economy. Finally, study reveal that different policy also contribute to strengthen the relationship of economic expansion and non-renewable energy consumption. Study also explores the significant positive association between renewable energy consumption and growth. Based on the discussion above, we hypothesize that:

H2: Non-Renewable energy consumption has a significant and positive influence on economic growth.

2.3 Renewable Energy Consumption and Environmental Degradation

Sompolska-Rzechuła et al. (2024) analyzed the influence of renewable energy consumption on environmental degradation. The study covers the year of 2015, 2019 and 2021 in European Union countries. Results reveal that the renewable energy helped to maintain

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sustainable environment, energy security and increase the quality of life. Authors also predict that the utilization of renewable energy source leads to low environmental degradation and high degradation occurred with the use of traditional energy source. Rizwanullah et al. (2024) evaluate the effect of different environmental and economic variable that influence the environmental degradation. These variables include FDI, TO, industrialization, environmental diplomacy and renewable energy consumption. Data sample contain all G20 countries and African Union, cover the period from 1991 to 2020. Various type of test was used to confirm the IV and DVs relationship. Finding show that the industrialization, FDIs, TO and ecological diplomacy have significant influence on environmental degradation. Renewable energy consumption has significant negative impact on environmental degradation which reveal that the use of renewable energy consumption protects the environment. G20 nations implementing new rules and regulations to handle the climate issue. However, Hussein and Mohamed (2024) scrutinized the effect of renewable energy and globalization on environmental degradation in Somalia. Study period of this study is 1990 to 2020. Results exposed that globalization has blended influence. Renewable energy consumption contributes negatively on environmental degradation. In order to promote the natural environment study recommends investing in renewable energy source and adopting eco-friendly strategies to mitigate the environmental degradation. Additionally, Nam et al. (2024) analyzed the impact of association between renewable energy, FDIs, economic development with environmental Quality. Sample Data start from 1986 to 2022 of the Vietnam country. NARDL strategy is used to detect the increasing and decreasing trends. Research discovered that renewable consumption in Vietnam increased from 6% to 16% in 1986 to 2022 which reduced the outflow of CO2 and enhance the environment quality. These statistics proved that renewable energy source play vital role in sustain eco-friendly environment. Based on the discussion above, we hypothesize that:

H3: Renewable energy consumption has a significant and negative relationship with environmental degradation.

2.4 Non-Renewable Energy Consumption and Environmental Degradation

Ahmat et al. (2024) exposed the correlation between non-renewable energy consumption and environmental degradation and also explored the relationship between energy consumption & growth on CO2 emissions. Spinning period of study was 1986 to 2021. ARDL finding show that the non-renewable energy consumption contributes to environmental degradation. Activities like fossil fuel consumption, Deforestation damages the environmental severely and enhance the temperature. Non-renewable energy consumption increases the greenhouse gases lead to global warming. In 2020 emissions of greenhouse gases was 48% increased above its pre-industrial level. However, Dansofo et al. (2024) examined the correlation between non-renewable energy consumption and growth on environmental degradation. Study covers the period from 1980 to 2020 in Nigeria. Finding exposed that non-renewable energy consumption contribute significantly and positively on environmental degradation. Fossil fuel consumption enhances the CO2 emissions and cause climate change. Meanwhile economic growth also positively contributes to environmental degradation. Additionally, Liu et al. (2017) analyzed the association among non-renewable energy consumption and CO2 emissions also reveal the influence of energy consumption and economic growth on CO2 emissions in four south Asian countries. Various analysis technique includes ARIMA, Granger Causality, and Environmental Kuznets Curve (EKC) were used to confirm the relationship between IVs and DVs. Results exposed that non-renewable energy consumption has significant positive association with environmental degradation while other variable have negative effect. Based on the discussion above, we hypothesize that:

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H4: Non-Renewable energy consumption significantly contributes to environmental degradation.

3. Data and Methodology

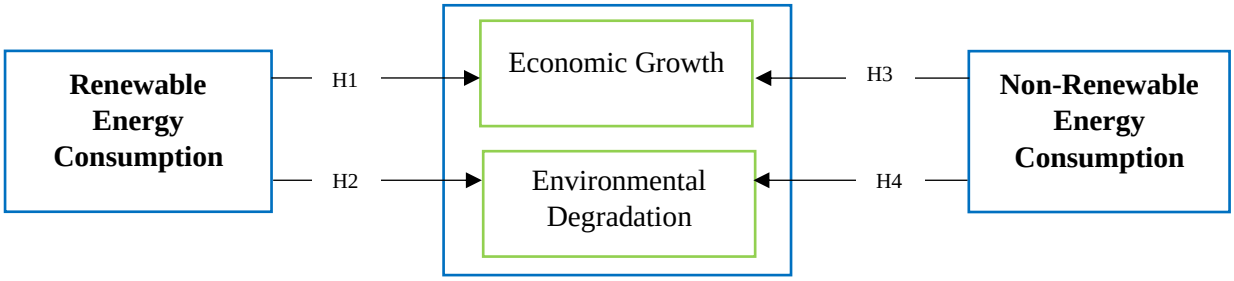

Figure 1. Conceptual Framework of the current study.

3.1 Database and Variables

To determine the relationship between energy consumption (renewable energy and non-renewable energy), economic growth and environmental degradation we select panel dataset compose of G20 countries spanning period from 2010 to 2023. Total 19 countries are included as sample and each have 14 years of data. Additionally, our dataset has large no of cross sectional (N) observation as compared to time (T), highlighting the greater coverage of individual entity then time period. We employ two independent variables include renewable energy (lnREC) and non-renewable energy consumption (lnNREC). Additionally, we used two dependent variable, economic growth (lnEG) and environmental degradation (lnED). Economic growth is assessed by annual percent change in real GDP whereas environmental degradation is estimated by CO2 outflow from fossil fuel and industry in billion tones. Also, we used Trade openness (lnTO), foreign direct investment (lnFDI), green investment (lnGE) and COVID 19 as control variable.

In order to standardized all variable unites we transformed all variable in logarithmic form which reduced the skewness of data set and increase the accuracy (Appiah et al., 2023; Sun et al., 2022). We collect data from different source in order to construct a holistic panel data set. Particularly, Our World in Data granted insight into renewable energy, non-renewable energy consumption and environmental degradation. Data of economic growth and green investment were obtained from International Monitory Fund. Additionally, statics relating to Trade openness and foreign direct investment is acquired from WORLD Development Indicator. This structure of panel data exclusively combine the elements of Cross section and time series which higher the degree of freedom, lower collinearity, enhance efficiency and increase information value (Hsiao, 2022; Baltagi, 2008). Table1 explains the variable one by one.

3.2 Methodology

Following model is utilized to forecast the impact of renewable energy consumption on economic growth and environmental degradation as well as non-renewable energy consumption on economic growth and environmental degradation which is the main goal of this study. To scrutinize this impact, we use following regression model.

$$\ln EG_{i,t} = \propto + \beta_1(\ln REC_{i,t}) + \beta_2(\ln NREC_{i,t}) + \beta_3(\ln FDI_{i,t}) + \beta_4(\ln TO_{i,t}) + \beta_5(\ln GI_{i,t}) + \beta_6(COVID19_{i,t}) + \varepsilon_t \quad \textbf{(1)}$$

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$$\ln ED_{i,t} = \propto + \beta_1(\ln REC_{i,t}) + \beta_2(\ln NREC_{i,t}) + \beta_3(\ln FDI_{i,t}) + \beta_4(\ln TO_{i,t}) + \beta_5(\ln GI_{i,t}) + \beta_6(COVID19_{i,t}) + \varepsilon_t \quad \textbf{(2)}$$

Here, $\propto$ indicate the constant term, β symbolized the slop of coefficient, while the subscript t represents the time frame as well as subscript i illustrate the count of cross sections (countries). ε_t Represented the error term that tackle any unapparent variables that may influence the dependent variable. Eq 1, represent the impact of βlnREC, βlnGI, βlnTO, βlnFDI, βlnNREC and βCOVID19 on economic growth (lnEG). Similarly, Eq 2, show the relationship between βlnREC, βlnGI, βlnTO, βlnFDI, βlnNREC and βCOVID19 on environmental degradation (lnED). Fig 1 illustrates the conceptual model of the study.

Table 1. Variables Description

Variables	Acronyms	Measurement	Sources
Independent Variables			
Renewable Energy Consumption	lnREC	Primary energy consumption %	Our world in data
Non-Renewable Energy Consumption	lnNREC	Fossil fuel per capita (kwh)	Our world in data
Dependent Variables			
Economic Growth	lnEG	Real GDP growth (annual percent change)	IMF
Environmental Degradation	lnED	CO2 emissions from fossil fuel and industries, measured in billion tonnes.	WDI
Control Variables			
Trade Openness	lnTO	Trade (% of GDP)	WDI
Foreign Direct Investment	lnFDI	The net value of foreign direct investment (FDI) equity flows into a country, quantified in terms of current U.S. dollar	WDI
Green Investment	lnGI	Funds allocated by the government for environmental protection as a percentage of GDP	IMF
COVID19 Pandemic	COVID19	It indicates the presence (1) or absence (0) of COVID-19 epidemic influence	Binary Variable

4. Results interpretation and discussion

To reveal the underlying characteristics of our data, we applied meticulous statistical techniques. Ensure that the regression method must correctly reflect the data's properties. After thoroughly analysis we employed specific test to delineate the property of data and present key empirical finding to assist statistical interferences about the outlined relationship. We primarily

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used two main statistical techniques; PCSE supplemented by FGLS for robustness verification, due to their ability to address autocorrelation, heteroskedasticity and cross-section dependence.

Table 2 represents the descriptive statistics of data. Top and lower bound of data is maximum and minimum value of data and all data must exist between these two limits. Data deviation from mean value represents the standard deviation. Higher standard deviation is not ideal for analysis because it aggravate the issue of outliers (Noor et al., 2023). Total observation of lnEG is 231, its mean value is 1.002. maximum and minimum value are 2.434 and -1.609 respectively. lnFDI have 260 observation and rest of data have 266 observations. lnED mean value is 20.325 while maximum value is 23.2 which shows G20 countries significantly contribute to environmental degradation, and minimum value is 17.886 lnNREC maximum value is 10.563 and minimum value is 6.603 while lnREC maximum and minimum value is 3.912 and .262 respectively. This statistic represents that G20 countries consume non renewable energy sources to meet their energy demand than renewable energy.

Table 2. Descriptive Statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
lnEG	231	1.002	0.803	-1.609	2.434
lnED	266	20.325	1.114	17.886	23.2
lnREC	266	2.367	0.709	.262	3.912
lnNREC	266	7.979	0.94	6.603	10.563
lnFDI	260	22.829	5.668	-1.273	26.96
lnTO	266	3.919	0.36	3.113	4.659
lnGI	266	-0.717	0.709	-3.331	0.232
COVID19	266	0.286	0.453	0	1

Figure 2 describe the paiwise correlation analysis with the variance inflation factore (VIF). This analysis is used to determine the direction and strength of linear relationship among two different variable. Mansfield & Helms (1982) suggest that high coefficient value among the variable may arise the issue of multicollinearity. In our results, correlation values are fall within the acceptable limits which represents the less chance of multicollinearity between variable. Exclude that variable from econometric model which create problem because high correlation can disturb the analysis. lnRE is positively correlate with lnEG (0.06) and negative with lnED (-0.08). Highest positive correlation is existing between the lnNREC and lnED (0.94) which mean lnNREC is the major source of environmental degradation, lnNREC is also positively associate with the lnEG (0.2).

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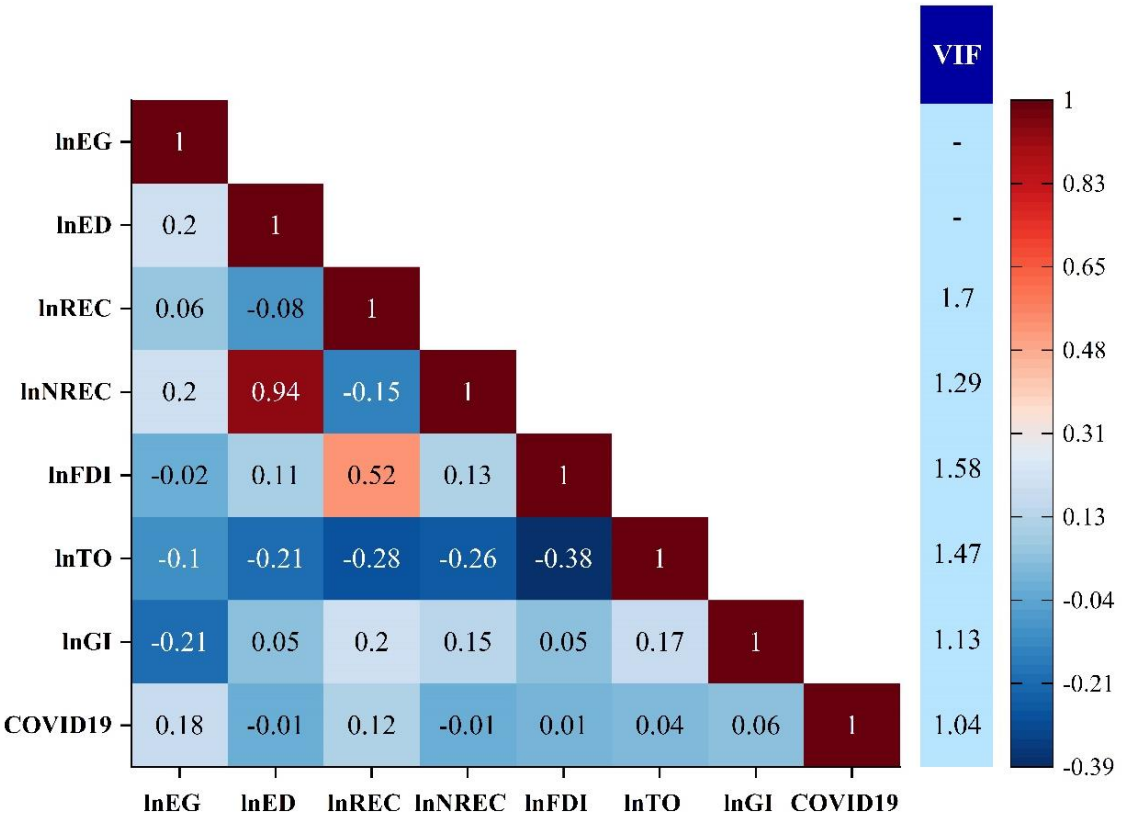

Figure 2. Pairwise Correlation and VIF Results

Besides pairwise correlation, we also performed VIF analysis to strengthen our pairwise correlation results of multicollinearity. This statistical technique also used to diagnose the multicollinearity in data. Variable which VIF value is greater than 10 leads to multicollinearity (Studenmund, 2000). In our finding VIF are optimistic finding because all variables VIF value is almost 1 which demonstrate absence of multicollinearity in data.

Table 3 presents the findings of unit root tests. In order to ensure the stationarity of the data, we utilized three-unit root tests. These tests include Breitung, Im–Pesaran–Shin and Fisher-type (ADF). The results of all three-unit root tests shows that mostly variables are stationary are first difference. Therefore, we can say that stationarity exist in our dataset. In Table 4, we conduct cross sectional dependency test with the help of Pesaran CD and Breusch pagan LM test. Model represents the significant cross section dependency because their p value is less than 1%. Model 2 also exhibit these results due to less then1% p value. These statistics show that our data represent Cross section dependency which means we reject our null hypothesis of Cross section dependency.

Table 3. Findings of unit roots tests

Variable	Breitung		Im–Pesaran–Shin		Fisher-type (ADF)	
	Level	First Difference	Level	First Difference	Level	First Difference

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lnEG	-6.1603***	-9.9102***	-7.3964***	-9.1177***	124.7676***	538.1677***
lnED	3.0618	-6.1537***	1.7076	-7.1522***	22.4316	263.8383***
lnREC	4.3962	-5.2652***	1.4683	-7.4037***	33.0505	301.8195***
lnNREC	2.7632	-7.5992***	1.9887	-6.7592***	21.6698	223.3398***
lnFDI	-6.9561***	-8.5755***	-4.5708***	-7.9250***	105.2921***	342.6278***
lnTO	-0.9625	-6.7007***	-2.0509**	-6.1842***	53.2220*	173.1297***
lnGI	5.1930	-7.3100***	-1.8120**	-5.9167***	326.8834***	448.8746***
COVID19	0.0000	-10.2225***	4.5955	-6.6603***	4.6078	179.1764***

Table 4. Findings of Cross-Sectional Dependence Tests

	Model 1	**Model 2**
Pesaran CD test	6.860*** (0.0000)	2.663*** (0.0077)
Breusch-Pagan LM test	567.613*** (0.0000)	413.625*** (0.0000)

Modified Wald test for GroupWise heteroskedasticity is present in Table5. Wald test verify the heteroskedasticity in data which reveal that homoscedasticity is also present. With the help of this finding we reject our null hypothesis of homoscedasticity. In model 1 χ^2 value is 321.07*** which is significant at 1% significant level. In model 2, χ^2 value is 1515.42*** which is also significant at 1% significant level. In Table 5, Wooldridge test exposed the existence of autocorrelation in data on the basis of this result we reject our null hypothesis. Moreover F-state value of model 1 is 5.313*** and model 2 is 31.842*** which is significant at 1% significant level. Group wise heteroskedasticity is present in data by applying Modified Wald test and confirm the presence of autocorrelation by applying Wooldridge test.

Table 5. Results of Heteroskedasticity and Autocorrelation Tests

Modified Wald test for GroupWise heteroskedasticity		
	Model 1	**Model 2**
χ^2	321.07***	1515.42***
Sig	0.0000	0.0000

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Accept/Reject	Accept	Accept
Wooldridge test for autocorrelation in panel data		
F-stat	5.313***	31.842***
Sig	0.0340	0.0000
Accept/Reject	Accept	Accept

4.1 Primary regression findings

In Table 6, we conduct PCSE as our main regression. Model 1 discovered that lnREC has significant and positive influence on economic growth with coefficient value is 0.1179**. When natural resources bequest is increased by 1% then economic growth is increased by 0.1179%. This finding show that natural resources play vital role in enhances the economic growth of G20 countries. Therefore we reject our null hypothesis and results support H1 that renewable energy consumption has significant positive impact on economic growth. Dirma et al. (2024) and Zehri (2025) also reveal that renewable energy is an important source to increase the economic growth. This finding shows that G20 countries turned their interest to lnREC to meet their energy need and economic expansion.

Besides model 1, we also describe the relationship between lnNREC and lnEG in model 2. Results reveal that lnNREC also have significant and positive influence on economic growth and have significant value is 0.1840*. These statistics show 1% increase in the use of fossil fuels, 0.184% increase the economic growth. Therefore, G20 countries economic expansion is heavily depends on the lnNREC. With these results we reject our null hypothesis and accept H2 that lnNREC has significant positive effect on economic growth. Researcher like Kahia et al. (2017) and Noor et al. (2023) have similar finding that lnNREC is the important for economic growth. In Past few decades, G20 countries population increase and also enhance the energy demand. To satisfy their energy need G20 nation strongly relay on lnNREC (Aboueata et al., 2021).

Table 6. Findings of PCSE Regression

Variables	**Model 1**		**Model 2**	
	Coef.	**p-value**	**Coef.**	**p-value**
lnREC	0.1179** (0.0526)	0.025	-	-
lnNREC	-	-	0.1840*** (0.0317)	0.000
lnFDI	-0.0135** (0.0071)	0.059	-0.00629 (0.0049)	0.204
lnTO	-0.1890** (0.0886)	0.033	-0.0464 (0.0863)	0.591

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lnGI	-0.2605*** (0.0459)	0.000	-0.2859*** (0.0570)	0.000
COVID19	0.3888 (0.2744)	0.157	0.4181 (0.2801)	0.136
_cons	1.5198*** (0.4398)	0.001	-0.4306 (0.5617)	0.443
N	260		260	
R-squared	0.1028		0.1380	
Wald chi²	88.00	0.0000	65.05	0.0000

PCSE regression analysis with lnED as DV is reported in Table 7. In model 1, association among the lnREC and CO2 is significant and negative. lnREC coefficient value is -0.3686*** which predict that the use of lnREC reduce the environmental degradation with no emissions of CO2. lnREC is a safe source of energy which protect environment. Due to these statistics, we reject our null hypothesis and accept H3, lnREC have significant and negative influence on lnED. Negative figure show that 1% increases in the use of lnREC decrease -0.3686% outflow of CO2. Metthew and Azebi (2023) and Sompolska-Rzechuła et al. (2024) also disclosed that lnREC reduce the environmental degradation and also help to maintain natural environment. Sustainable environment is more important in today's era. In order to tackle the environmental challenge G20 nations are implementing new rules and regulations for industries and shift interest to lnREC and green investment to reduce the environment from damage (Rizwanullah et al., 2024).

Table 7. Findings of PCSE Regression

Variables	**Model 1**		**Model 2**	
	Coef.	**p-value**	**Coef.**	**p-value**
lnREC	-0.3686*** (0.02881)	0.000	-	-
lnNREC	-	-	1.1501*** (0.0088)	0.000
lnFDI	0.0266*** (0.0031)	0.000	0.0050*** (0.0010)	0.000
lnTO	-0.7497*** (0.1193)	0.000	0.2262*** (0.0327)	0.000
lnGI	0.2277*** (0.0519)	0.000	-0.1770*** (0.0198)	0.000
COVID19	0.0404*** (0.0248)	0.104	0.0094 (0.0111)	0.399

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_cons	23.6805*** (0.5961)	0.000	10.0174*** (0.2210)	0.000
N	260		260	
R-squared	0.0877		0.8870	
Wald chi²	493.82	0.0000	132946.27	0.0000

In addition to address the impact of lnREC on lnED, model 2 present the results of lnNREC influence on lnED. Finding show that lnNREC has significant and positive influence on lnED with coefficient value is 1.1501*. This coefficient value suggests that 1% increase in lnNREC increase the 1.150% of CO2 emissions. These statistics support our H4 that lnNREC has significantly contribute to environmental degradation. Chein (2022) and Adeloka et al, (2022) support our finding. Our World in data (2024a) reveals that 15% increase from 2013 to 2023 in G20 nation. This figure shows the main reason of environmental degradation. Main culprit behind increases the emissions of CO2 is use of fossil fuel consumption by G20 countries which is increase by 15.93% (Our World in Data 2024b). G20 countries satisfy their energy demand thorough lnNREC which pollute environment.

4.2 Robustness check

Table 8 and 9 represent FGLS regression results, which we apply for robustness check. FGLS technique is utilized to predict the parameters of linear regression model when there is association between heteroskedasticity and error term. Beck & Katz (1995) reveal that as compared to PCSE, FGLS effectively deals with the issue in cross sectional dependency, autocorrelation and heteroskedasticity and also deliver accurate and precise estimation parameters. Table 8 represents the FGLS regression with lnEG as DV. Model 1 represent association between lnREC and lnEG is significant and positive have coefficient value is 0.1179**. In model 2, lnNREC has significant and positive relation with lnEG and having coefficient value is 0.1840***. Table 9 report the FGLS regression with lnED as DV. Model 1 show that lnREC has significant negative influence on lnED with coefficient value -0.3686***. In model 2, lnNREC has significant positive association with lnED with coefficient value 1.1501.

Table 9. Findings of FGLS Regression

Variables	**Model 1**		**Model 2**	
	Coef.	**p-value**	**Coef.**	**p-value**
lnREC	-0.3686*** (0.1146)	0.001	-	-
lnNREC	-	-	1.1501*** (0.0262)	0.000
lnFDI	0.0266** (0.0143)	0.062	0.0050 (0.0045)	0.266

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lnTO	-0.7497*** (0.2062)	0.000	0.2262*** (0.0741)	0.002
lnGI	0.2277** (0.0988)	0.021	-0.1770*** (0.0348)	0.000
COVID19	0.0404 (0.1501)	0.788	0.0094 (0.0522)	0.857
_cons	23.6805*** (1.0091)	0.000	10.0174*** (0.4492)	0.000
N	260		260	
Wald chi²	24.98	0.0001	2039.94	0.0000

Table 8. Findings of FGLS Regression

Variables	**Model 1**		**Model 2**	
	Coef.	**p-value**	**Coef.**	**p-value**
lnREC	0.1179** (0.0863)	0.032	-	-
lnNREC	-	-	0.1840*** (0.0548)	0.001
lnFDI	-0.0135 (0.0106)	0.203	-0.0062 (0.0092)	0.497
lnTO	-0.1890 (0.1584)	0.233	-0.0464 (0.1621)	0.775
lnGI	-0.2605*** (0.0772)	0.001	-0.2859*** (0.0755)	0.000
COVID19	0.3888*** (0.1199)	0.001	0.4181*** (0.1156)	0.000
_cons	1.5198** (0.7693)	0.048	-0.4306 (0.9843)	0.662
N	260		260	
Wald chi²	26.13	0.0001	36.49	0.0000

5. Conclusion and policy implications

Empirical analysis of study furnishes the relationship of both variable lnREC and lnNREC on growth and environmental degradation, considering G20 nations as sample for the year from 2010 to 2023. Results explored the complex but engaging narrative. LnREC and lnNREC play vital role in enhancing the growth of country but in the case of environmental degradation, both energy types have divergent results. However, renewable energy consumption has significant positive relation with economic growth with clean and sustainable environment. Evidence from study show that most of the countries in G20 nations such as UK, Canada shifts their energy demand toward lnREC by making more investment in green technology project and sustain healthy environment. Additionally, lnREC exhibit significant negative association with environmental degradation. Results show that renewable energy consumption decreases the emissions of CO2 and maintain natural environment. These finding promote the global policy initiative that is investing in green energy to achieve the economic expansion with sustainable environment.

In contrast, as a large emerging economic, G20 nations also struggling to balance their growth with mitigating environmental issue. In this paper besides renewable energy consumption impacts, we also find the influence of nonrenewable energy consumption on growth and environmental degradation. Finding reveals that nonrenewable energy consumption significantly contributes to economic growth and also contributes to environmental degradation. When fossil fuel burn, they emit CO2 gas which is the strongest source to damage the environment. G20 nations heavily depend on lnNREC as China and India where fossil fuel is major source of energy mix.

Both type of energy sources are vital for economic growth, they are considered the pillars of growth. But renewable energy consumption is a safe source of energy which contributes to healthy environment and sustain ecofriendly climate. lnNREC emit greenhouse gases which pollute the environment and change the climate condition. So, results reveal that G20 countries turn their interest toward renewable energy for satisfying their energy need and for boosting their economies. Ultimately, this study reveals the importance of renewable energy consumption as not only the tool for eco-friendly environment but also the driver of economic expansion. Emissions of CO2 can be only controlled by investing in the green energy projects. Therefore, policymakers of G20 nations shift their interest toward renewable energy projects and sustain healthy environment.

Despite this result, our study also has few limitations. The time frame of dataset may not properly reflect the long run trends and the influence of gradual policy changes. Furthermore our focus is G20 nations as a collective entity, regardless of differences in economies, geographical regions and energy consumption pattern. Due to these differences, we cannot fully analyze the relationship of our variable in the current study. To address these problems, future study could explore the G20 nations individually and cluster of country which has similar characteristics.

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