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Environmental Effects of Renewable and Non-Renewable Energy: Data from a Few Selected Group States

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ABSTRACT

This study empirically investigates and compares the impact of renewable and nonrenewable energy on the environment for twenty countries according to their energy usage. The annual panel data duration is from 1990 to 2022. The empirical outcomes for comparative analysis are based on panel non-linear ARDL approach to examine the long-run and short-run relationship. The findings show that the impact of renewable countries is much positive and far better for the environment as compared to those countries using fossil fuel. A feasible justification for the positive impact of renewable energy on the environment is that these counties are using good energy sources and modern environmental techniques. In addition, these countries have higher income and better governance than the nonrenewable countries. Further the shock of the income level is positive in the case of renewable countries. Whereas the countries having nonrenewable energy sources have negative effects. Therefore, it is mandatory to improve the income and energy usage level of these countries to minimize pollution.

Keywords: CO_2, Energy Consumption, Pooled Mean Group, Energy Development, Auto Regressive Distributed Lag, Income Level
JEL Classifications: Q20, Q30, Q56

1. INTRODUCTION

The significance of the discussion surrounding the effects of climate change has grown recently. The entire global climate is getting hotter every day. Thus, environmentalists are attempting to identify the mechanisms that could lead to an improvement in environmental quality. The combustion of coal, oil, and natural gas is releasing more carbon dioxide (CO_2) into the atmosphere because of the fast industrialization and urbanization of the world. For instance, when a region gets more urbanized, new obstacles to sustainable development appear, like the requirement for their economies to grow quickly, the demand for employment, and the requirement to use energy. (Levinson and Taylor, 2008)

Since it is impossible to transport, produce, and consume energy without hurting the environment, energy usage is mostly to blame for environmental concerns. The production of energy from non-renewable resources poses a significant risk to the environment because of the intensive types of harmful poisonous gases that are produced, which can have a devastating effect on both biotic and environmental components. An ecosystem is made up of both biotic and abiotic elements that work together to maintain the equilibrium of the surrounding environment. These days, a lot of environmentalists think that society is influenced by the three E's: Environment, energy, and economy. These three elements are all connected, either directly or indirectly. Large energy consumption by industry and households harms the quality of the environment in developing economies. Emerging economies may enhance energy efficiency through waste reduction in the environment. Developing economies rely on coal, gas, and oil to meet their energy needs (Cetin, 2018).

Economists and environmentalists argued that the world's environmental conditions are destroyed by excessive energy consumption from sources like electricity, gas, coal, and oil, which also generates a lot of trash due to high consumption rates.

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In addition, they disagree with the idea of a carbon tax since it is hard to quantify carbon emissions and, thus, hard to determine the appropriate level of taxation. Energy combustion has a beneficial effect on CO_2 emissions, according to (Irfan and Shaw, 2017; Saidi and Hammami, 2015), who also noted that this effect is nonlinear but still positive.

In addition, earlier research examined the effects of energy use on developing nations' environments. There has been a lot of research on the non-linear link between energy consumption and environmental deterioration, but the relationship between disaggregated energy consumption and carbon dioxide emissions has received the most attention. There will probably be serious negative effects on the environment if the globe does not adopt a more sustainable path for economic development. According to (Chandra Voumik et al., 2023), energy use plays a significant role in the rise of ecological toxins in SAARC nations.

Lower ecological quality and faster economic development are largely related to the insufficient use of resources, free trade in an open economy, and a lack of awareness of how nature is deformed. Developing countries, whose main energy source is fossil fuel, are unlikely to be able to increase GDP soon without compromising the environment (Abdallah et al., 2013; Abu-Madi and Rayyan, 2013). Modifying the effects of climate change will need a variety of strategies, including increased regulatory efforts, the use of green energy, increases in energy efficiency, and more effective enforcement of environmental laws (Allard et al., 2018).

Our research makes some contributions to the body of knowledge surrounding the environmental Kuznets curve (EKC) concept. This study observes the non-linear relationship between energy use and environmental quality to close this gap. Examining the non-linear relationship between energy use and carbon dioxide emissions across 20 nations is the main objective of this research. These countries are divided according to their energy usage. i.e., renewable, and non-renewable energy. This study also gives academics, individuals, and representatives the information, proof, and improved understanding they need. Government officials, legislators, and laypeople can all benefit from this study's evaluation and comprehension of the ways in which energy combustion impacts environmental quality. This study suggests environmentalists and policymakers use the tools they need to create both short- and long-term environmentally favorable policies.

2. LITERATURE REVIEW

The "Kuznets curve," so named after Russian economist Simon Kuznets, is an inverted U-shaped curve that depicts growth and income inequality in the 1950s. Admiring his hypothesis, (Grossman and Krueger, 1995) employed a similar method in 1995, substituting CO_2 emissions and economic development depending on environmental quality. Since then, numerous additional scholars have used a variety of econometric techniques to describe correlations between numerous variables based on the EKC hypothesis. To shed light on this subject, a review of the literature is required to compare studies and determine how different factors impact the state of the environment overall by raising CO_2 emissions.

(Hossain, 2011) examined the relationships between newly industrialized urbanized economies, trade openness, economic growth, and CO_2 emissions between 1971 and 2007. According to the study, there is unidirectional correlation between trade openness and urbanization as well as between economic growth and energy consumption and trade openness and urbanization. (Munir and Ameer, 2018) examined how urbanization, technology, and trade openness affect environmental deterioration in Asian rising economies over the long and medium terms. They discovered that there is evidence for the environmental Kuznets curve theory between economic growth and SO_2 emissions. (Shahbaz et al., 2011) examined the relationship between economics.

The EKC was validated by research examining fossil and renewable energy sources, and (Ali et al., 2018) showed that green energy sources had a beneficial impact in preserving environmental quality in four South Asian countries. (Khalid et al., 2021) attempted to evaluate the EKC for SAARC members by utilizing AMG, ECM, and D-H to determine the relationship between primary and REN financial development using the years 1990-2017. Pollution levels have risen in nations like Bangladesh and Sri Lanka to support growing energy consumption and improve financial development. It has been discovered that using renewable energy can help reduce pollution. Using the FMOLS and AMG estimation approach, (Zhang and Liu, 2019) demonstrate the invalidity of the EKC for ten Asian nations where non-renewable energy is the primary source of emissions. It has been discovered that switching to renewable energy helps balance environmental quality.

Given the detrimental effects of coal, oil, and gas on the environment, countries ought to support clean energy alternatives like wind and solar power that emit less pollution (Usman et al., 2022). (Ramzan et al., 2022) findings, which indicated that cleaner energy should be a top priority in energy policy to ensure sustainable economic growth, were consistent with the finding that non-renewable resources impose a significant environmental cost for the poor countries. (Mahmood et al., 2019) contended that the transportation sector, which is primarily fossil fuel-based and contributes significantly to CO_2 emissions in SAARC nations, supports the EKC hypothesis of an inverted U-shaped structure in the region.

In order to maintain acceptable carbon footprints, wealthier economies have increased their reliance on alternative energies, including nuclear energy. (Usman and Makhdum, 2021) discovered that nuclear sources significantly reduce pollution after using CS-ARDL to investigate how human capital and nuclear energy enhanced ecological integrity in 12 advanced economies between 1980 and 2015.

A number of studies have examined how switching to renewable energy sources will affect environmental quality. (Afshan et al., 2022) observed that environmental policy rigor, ecological innovation, and the shift to renewable energy all had an impact on the ecological footprint of OECD economies from 1990 to 2017. They did this by using the MM-QR approach, and they found that because green energy has a negative reputation, sustainable development requires encouraging it. From 1990 to 2013, (Saidi and Mbarek, 2016) establish a correlation between the usage of nuclear power and clean energy, emissions, and real GDP for nine developed countries, considering labor and capital.

The significance of renewable energy for economic growth was demonstrated by the short-term unidirectional causation between REN and real income per capita (GDPP), the long-term bidirectional causality between renewable energy and real GDPP, and the unidirectional causality between GDP and emissions. It has been demonstrated that nuclear energy can help reduce environmental contamination by (Ahmad and Mahmood, 2013), (Hassan et al., 2020), (Majumder et al., 2023), and (Voumik et al., 2022). (Victor Bekun, 2022) research demonstrated the efficiency of green energy in reducing CO_2 emissions by showing a negative relationship between renewable energy and CO_2 emissions and a positive relationship between non-renewable energy, economic growth, and CO_2 emissions in India. The EKC hypothesis and tourism-induced CO_2 emissions in E7 economies were demonstrated by (Victor et al., 2022). The validity of the EKC theory was established by (Huang et al., 2022), who demonstrated that using renewable energy sources considerably slows down global warming. In contrast, the environment in developing nations deteriorates when non-renewable energy is used.

Hence, it is explained from the previous studies, most research in the literature investigated the non-linear relationship between environment and economic growth using the environmental Kuznets curve (EKC) hypothesis. Moreover, the nonlinear relationship between the environment and energy use is also found in a few studies. However, our main concern is to check and compare the impact of both renewable and nonrenewable energy on the environment in our study sample.

3. RESEARCH METHODOLOGY

This study is based on Environmental Kuznets Curve (EKC) hypothesis. According to the EKC hypothesis, rising energy consumption eventually causes environmental degradation with rising production activities, which is directly correlated with economic growth.

The relationship between energy consumption and environmental quality is examined in this study using the following econometrics models, where energy is divided into renewable and nonrenewable sources.

$$CO_2 = f\,(GDP, EC^{+}, EC^{-}, PD)\ldots\ldots \quad (A)$$

$$CO_2 = f\,(GDP, EC^{+}, EC^{-}, PD)\ldots\ldots \quad (B)$$

Where CO_2 is carbon dioxide emissions metric ton per capita, GDP is income per capita constant 2015, EC is energy consumption (renewable and nonrenewable) in kg per capita and PD is population density in mass per unit volume. The above model "A" represents the countries using renewable energy sources, whereas the model "B" indicates the countries consuming nonrenewable energy sources.

This study uses the annual panel data for twenty countries with different energy sources. The data duration is from 1990 to 2022. All the data is collected from world development indicators (WDI).

Panel data is superior to time series and cross-sectional data because it illustrates the heterogeneity and particular effects of the cross section. Large sample sizes boost the results' dependability and make the estimation more reliable. Furthermore, panel data has greater information, less collinearity, and higher efficiency, it is more valuable (Baltagi, 2013; Wooldridge, n.d., 2010).

In the first phase, stationarity tests are made on the variables to prevent false regression results and misleading findings. Tests for variable stationarity include the LLC, IPS, and Fisher-ADF panel unit root tests. For pooled data, (Levin et al., 2002) provided the panel unit root test of Levin, Lin, and Chu (LLC). The LLC test is recommended if the time period was between 5 and 250 and the number of nations was between 10 and 25. According to (Im et al., 2003), the Im, Pesaran, and Shin (IPS) panel unit root test assumes that the variables have a normal distribution, finite heterogeneous variance, and zero mean. The concept of Fisher (1932) is used by Maddala and Wu (1999) to illustrate the Fisher-ADF unit root test.

The pooled mean group (PMG) or panel auto regressive distributed lag (ARDL) model is a method for estimating non-stationary dynamic panels that was developed by (Pesaran and Shin, 1995). PMG is used to study heterogeneous dynamic concerns across countries and to assess the long- and short-run association among the variables. The general form of the panel ARDL or PMG model is as follows.

$$Y_{it} = \sum\nolimits_{j=1}^{p} \lambda_{ij} Y_{i,t-j} + \sum\nolimits_{j=0}^{q} \delta_{ij} X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (1)$$

where μi represents the fixed effects, λij is the coefficient of the lagged dependent variable, δij is the (k × 1) coefficient vector of independent variables, εit is the error term, i (1, 2,… N) is the number of cross sections, and t (1, 2., T) is the number of times. Yit is the dependent variable in this example. A vector error correction model can be re-parameterized as follows for equation (1):

$$\Delta Y_{it} = \theta_i ECT_{it} + \sum\nolimits^{p-1} \lambda^{*}_{ij} \Delta Y_{i,t-j} + \sum\nolimits_{j=0} \delta^{*}_{ij} \Delta X_{i,t-j} + \mu_i + \varepsilon_{it} \quad (2)$$

Where, $ECT_{it} = \phi_i Y_{i,t-1} - \beta_i X_{it}$

Error correction term (ECT) parameter. The speed of adjustment is given by θi. Whereas the negative sign indicates convergence in the short term, the ECT shows the rate at which the variable is adjusted towards the long-run equilibrium. On the other hand, this study's objective is to examine the nonlinear relationship between energy use and panel carbon dioxide emissions. The linear ARDL model of (Pesaran and Shin, 1995) and (Im et al., 2003) served as the foundation for the nonlinear ARDL (NARDL) framework developed by (Shin et al., 2013). He divided a stationary variable into positive and negative variations using the methods of (Granger and Yoon, 2002). Consequently, the two components that make up the partial sum of the variables for a variable X are:

$$X^{+} = \sum_{j=1}^{t} \Delta X_{j}^{+} = \sum_{j=1}^{t} \max(\Delta X j, 0) \quad (3)$$

$$X^{-} = \sum_{j=1}^{t} \Delta X_{j}^{-} = \sum_{j=1}^{t} \max(\Delta X j, 0) \quad (4)$$

The long-run relationship between Y and X in a nonlinear frame is denoted as,

$$Y_t = \beta^{+} X_t^{+} + \beta^{-} X_t^{-} + \mu_t \quad (5)$$

$$X_t = X_0 + X_t^{+} + X_t^{-} \quad (6)$$

where X+ and X− are scalars of decomposition partial sums, and β+ and β− are long-run parameters. To accomplish the goals of this study, the panel non-linear ARDL model is estimated by combining the panel ARDL approach of (Pesaran, 2004) with the NARDL methodology of (Pesaran et al., 2004). Therefore, compared to NARDL and panel ARDL, our panel nonlinear ARDL methodology has the following three advantages. It first quantifies the data's non-linear asymmetries. It also assesses the impact of data heterogeneity. Finally, it makes more sense when there is a mixed order of variable integration. (Salisu and Isah, 2017) employed a panel non-linear ARDL model to investigate the impact of exchange rate pass-through on import prices, whereas (Rapsikevicius et al., 2021) used to investigate the relationship between stock prices and oil prices, a panel nonlinear ARDL model was utilized.

Hence, panel non-linear ARDL model can be stated as:

$$\Delta Y_{it} = \theta_i ECT_{it} + \sum_{j=1}^{p-1} \lambda^{*}_{ij} \Delta Y_{i,t-j} + \sum_{j=0}^{q-1} (\delta^{*}_{ij} \Delta X^{+}_{I,t-j} + \delta^{*}_{ij} \Delta X^{-}_{i,t-j}) + \mu_i + \varepsilon_{it} \quad (7)$$

where, $ECT_{it} = \beta^{+} X_t^{+} + \beta^{-} X_t^{-}$

Additionally, diagnostic tests have been used in the study to ensure the validity of the findings. The Jarque-Bera test (Jarque and Bera, 1980) is utilized to assess normality, while the cross-sectional dependence is determined by the Breusch-Pagan LM test. On the other hand, the short-run asymmetric causal link between the variables is determined using the Granger causality test. The following Table 1 describes the summary statistics for renewable and nonrenewable countries.

4. RESULTS AND DISCUSSION

The variable's order of integration is verified using the Fisher-ADF (F-ADF) panel unit root test, Im, Pesaran, and Shin (IPS), Levin, Lin, and Chu (LLC), and Schwarz information criteria (SIC) for the lag length criteria. The findings are presented in Table 2. Apart from energy usage, which displays a mixed order of integration, the results demonstrate that all the variables are integrated in order of one. None of the variables are integrated at order two.

The estimation of the long- and short-run parameters follows the suggestions made by (Pesaran, 2004). First of all, we found the results for renewable countries as it is presented in Table 3. In the long run estimation, the first variable energy consumption has a negative and significant effect on emissions. Which clearly states, in the developed nation by using renewable sources, we can protect our environment from harmful conditions. Same as energy consumption, its square form also has the same impact on Co_2. And the income per capita also has negative and significant results for Co_2. This indicates, in the renewable countries the ecological system will be more positive by more income. But population has a positive and insignificant impact on the environment, which indicates the countries having more population can destroy the environment badly. In addition to this, to measure the short-run estimations, the panel non-linear ARDL model is converted into an error correction model (ECM). The error correction term (ECT), whose negative value denotes short-term convergence, is a rate of adjustment that shows how quickly variables adapt towards long-run equilibrium. The negative and significant ECT tells us the long run relationship exists between all variables.

Table 1: Descriptive statistics

Variable	Mean	Median	Maximum	Minimum	Std. Dev
Renewable countries					
$LNCO_2$	1.67	1.81	2.85	0.27	0.67
LNEC	7.96	8.18	9.05	6.43	0.70
LNGDP	10.04	10.34	11.28	8.21	0.81
LNPD	3.61	3.08	5.62	1.12	1.24
Non-renewable countries					
$LNCO_2$	1.77	2.23	3.01	0.43	0.98
LNEC	7.85	8.26	9.04	5.86	0.92
LNGDP	9.19	9.34	10.94	6.27	1.29
LNPD	4.81	4.62	6.26	1.12	1.57

It indicates that environmental pollution tends to decrease, and environmental quality is protected when the policymakers and central authorities increase the use of renewable energy resources. The nonlinearity connection between renewable energy and ecological system is validated by the large divergence in magnitude between the positive and negative signs of the renewable energy coefficient. These findings are in line with (Usman and Makhdum, 2021) for the BRICS-T countries and (Usman and Nesrine, 2021) for the 15 most polluted countries support this conclusion. The economy and ecology benefit twice when nations switch from using fossil fuels to alternate or renewable energy sources (Huang et al., 2022).

First, energy produced through renewable energy projects reduces the likelihood of air pollution and eliminates the need for fossil fuels and greenhouse emissions. Subsequently, increasing their energy mix supply and shifting away from imported fossil fuels and non-renewables benefits their nation as well (Khalid et al., 2021).

Moving towards the nonrenewable countries, where the results are bit opposite to renewable countries. In the long run estimation, Table 4 describes energy consumption has a positive and significant consequence on emissions. Which obviously describes, in the developing nation by using nonrenewable

Table 2: Unit root test

Variables	LLC		IPS		F-ADF	
	Renewable countries					
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)
$LNCO_2$	2.195	−5.812***	3.047	−6.992***	12.854	90.406***
LNGDP	4.175	−7.484**	−0.115	−8.564**	22.063	114.51**
LNEC	−2.148**	………	−0.563	−8.395**	24.566	112.58**
LNPD	−3.992	4.472***	0.883	1.162***	39.732	18.490***
Non − renewable countries						
$LNCO_2$	2.189	−1.290***	0.611	−4.430***	29.655	63.563***
LNGDP	7.067	−2.147**	−0.076	−4.465**	37.356	89.157**
LNEC	−5.814	6.945**	−3.184*	…….	32.156	70.297**
LNPD	−1.763	5.402***	0.673	1.192***	29.305	28.543***

***, **, and * show significance at 1%, 5%, and 10% level respectively

Table 3: PMG model for renewable countries

Dependent variable: CO_2			
Long run results			
Variables	Coefficient	T statistics	P-value
LNEC	−0.073	−10.823	0.076*
LNEC2	−5.901	−6.588	0.015***
LNGDP	−0.076	−8.741	0.021**
LNPD	0.043	0.464	0.162
Short run results			
LNEC	−0.074	0.311	0.056*
LNEC2	−5.437	−0.133	0.013***
LNGDP	−5.845	0.979	0.034**
LNPD	−0.600	−0.390	0.191*

***, **, and * show significance at 1%, 5%, and 10% respectively

Table 4: PMG model for non-renewable countries

Dependent variable: CO_2			
Long run results			
Variables	Coefficient	T statistics	P-value
LNEC	8.090	0.652	0.051*
LNEC2	6.054	6.792	0.032**
LNGDP	0.187	16.831	0.045**
LNPD	1.805	0.050	0.097*
Short run results			
LNEC	−0.013	−1.595	0.054*
LNEC2	−8.798	1.599	0.010***
LNGDP	−0.076	−0.909	0.065*
LNPD	−8.248	−0.766	0.144**

***, **, and * show significance at 1%, 5%, and 10% respectively

sources, we can't protect our environment. Because these countries are still using fossil fuels, coal, gas etc. The square form of energy consumption has a positive impact on co2, meaning that in the long run by using more nonrenewable sources the country's environment will be more polluted. And the income per capita and population has a positive impact on the environment. As in the lower middle-income countries, people are having less income with the growing population. Which leads to harm to the environment of a society. The short-term ECT has the same outcome as Table 3.

The development of environmentally related technologies helps to overcome the energy consumption of fossil fuels, which reduces the amount of energy utilized and supports sustainable development (Usman et al., 2022). However, there has been a notable increase in the usage of environmental technologies linked to the use of alternate and cleaner energy sources as well as a reduction in the environmental imprint. Technologies about the environment will encourage green growth and serve as a reward for the lower income nation environmentally sustainable performance.

In this sense, considering the detrimental effects of technology related to the environment will raise the degree of pollution. These results demonstrate how poorly the government organizes its investments in technologies relevant to the environment. Developing countries ought to draw attention to their investment trends in environmentally related technology in particular, to mitigate the strain on the environment concerning its pollution level. Unfortunately, these states lack cleaner, cutting-edge technologies, which presents numerous obstacles in the green economy. The circular economy is emphasizing the influence of innovations more since it is rethinking the industrialization process (Rosa et al., 2019).

Additionally, a few residual diagnostic tests for autocorrelation and multicollinearity are also conducted in this investigation. There is no statistically significant correlation between the explanatory variables, as indicated by the centered VIF result of <5%. The null hypothesis, which states that there is no link between the error term observation and any other observation, is accepted by the Brensch-Godfrey serial correlation LM Test. Endogeneity, heteroskedasticity, and cross-sectional dependence are investigated using a PMG model. Given that the related variables have probability values larger than 5%, the model is well-fitted. A summary of the residual diagnostic test is given in Table 5.

Finally, after evaluating the asymmetric long-run and short-run results, the findings of asymmetric Granger causality tests are stated in Table 6. Conclusions show that in the case of renewable countries unidirectional connection leads from CO_2 emission to GDP and EC, whereas bidirectional casualty exists between CO_2 and PD. On the other hand, nonrenewable states CO_2 has bidirectional relation with EC, but unidirectional casualty is with GDP and PD.

Table 5: Diagnostic test

Multicollinearity		Endogeneity test			Heteroskedasticity dependent variable: (Resid) 2		
Variable	VIF	Variable	t-stat	P-value	Variable	t-stat	P-value
Renewable countries							
CO_2	1.73	Resid CO_2	1.14	0.22	CO_2	1.20	0.11
LGDP	1.37	Resid LGDP	1.87	0.10	LGDP	1.55	0.15
LEC	1.79	Resid LEC	1.55	0.25	LEC	1.38	0.35
LPD	1.56	Resid LIND	1.67	0.27	LIND	−0.14	0.57
Non-renewable countries							
CO_2	1.68	Resid LPD	1.65	0.36	LPD	1.19	0.33
LGDP	1.49	Resid LTOP	1.39	0.44	LTOP	0.14	0.40
LEC	1.39	Resid LEC	1.65	0.35	LEC	1.83	0.29
LPD	1.26	Resid LIND	1.47	0.19	LIND	−0.21	0.67

Table 6: Granger causality test

Variables	F-statistics	Causality
Renewable countries		
EC~CO_2	0.16	Yes
CO_2~EC	2.52*	No
GDP~CO_2	5.53	Yes
CO_2~GDP	0.12***	No
PD~CO_2	4.22	Yes
CO_2~PD	4.28**	Yes
GDP~EC	5.89***	No
EC~GDP	1.70	Yes
PD~EC	6.07**	Yes
EC~PD	6.28	Yes
PD~GDP	2.73*	Yes
GDP~PD	5.41**	No
Non-renewable countries		
EC~CO_2	3.89**	Yes
CO_2~EC	8.06***	Yes
GDP~CO_2	5.88***	Yes
CO_2~GDP	0.29	No
PD~CO_2	0.53*	Yes
CO_2~PD	1.56	No
GDP~EC	5.37	No
EC~GDP	0.04	No
PD~EC	1.91	Yes
EC~PD	1.20	No
PD~GDP	3.84**	No
GDP~PD	1.77*	No

***, **, and * show significance at 1%, 5%, and 10% respectively

5. CONCLUSION AND RECOMMENDATIONS

Energy cannot be produced, transported, or used without negatively affecting the environment. While industry and household consumers use a lot of energy and harm the environment, developing countries rely on coal, gas, and oil to meet their energy needs. In contrast, nations that use renewable energy do a far better job of preserving the environment. Since renewable resources like biomass, wind, and water may be recycled and have very less octane number. This is unquestionably a wise choice for a national eco system. This research examines the nonlinear relationship between energy consumption, both renewable and nonrenewable—and carbon dioxide emissions across 20 nations. Non-linear relationships have an environmental Kuznets curve (EKC) hypothesis as their theoretical foundation. Annual panel data from 1990 to 2022 are used in the study and investigates the long-run and short-run relationship using the panel non-linear ARDL approach.

In order to guarantee a future with sustainable energy, each of these tactics is essential. For instance, encouraging the use of renewable energy through R&D and subsidies can help lower costs and increase accessibility to these technologies. In a similar vein, imposing carbon pricing and more stringent emission controls can generate financial incentives to cut back on the use of fossil fuels. Another important area is promoting energy efficiency, which benefits both non-renewable and renewable energy sources by directly lowering the overall energy demand. Encouraging sustainable development and improving environmental protection will make sure that ecosystems and biodiversity are preserved as we move toward cleaner energy.

Finally, acknowledging the global character of energy production and use requires international cooperation and technological transfer. Together, nations may exchange assets, expertise, and knowledge.

There are environmental restrictions on both non-renewable and renewable energy sources, and solving these issues calls for a well-rounded strategy. Overcoming problems with land use, material demand, and intermittent is critical for renewable energy. When it comes to non-renewable energy, the main priorities should be controlling resource depletion, minimizing environmental harm, and avoiding geopolitical and economic hazards. Policymakers, companies, and communities may create more sustainable energy policies that reduce environmental effects and advance long-term energy security by being aware of these constraints.

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