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Analyzing Environmental Kuznets Curve (EKC) Hypothesis in case of Pakistan: The Role of Renewable Energy Consumption on Carbon dioxide (CO_2) Emissions (Evidence from 1991 to 2021)

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ABSTRACT
Testing Environmental Kuznets Curve (EKC) for Pakistan and the role of renewable energy consumption of CO_2 emissions within this framework. We use Annual time-series data from 1991-2021 from world ank. Autoregressive distributed lag (ARDL) approach was used for analysis since the variables were mix of I(0) and I(1). CO_2 emissions, GDP per capita, GDP per capita squared and energy use were analyzed to test does economic growth follows inverted U-shaped pattern with environmental degradation (model 1). Then renewable energy consumption was added to it, whether it reduces emissions (model 2). For both model the coefficient of LN_GDPC shows positive and its squared negative sign suggesting EKC pattern but are statistically insignificant. ARDL bound test confirms long-run cointegration between variables. coefficients of Renewable energy consumption (model2) show negative sign but is statistically insignificant. The findings suggest Pakistan is on rising part of EKC meaning economic growth increases CO2 emission. Environmental improvement for Pakistan requires a strong expansion of clean energy rather relying on economic growth to reduce pollution.

Key words: Environment Kuznets Curve (EKC), Environmental Degradation, CO_2 Emissions, Fossils Fuels, Renewable Energy Consumption, Sustainable Growth, Cointegration, ARDL Bound Test, ECM.

Introduction

Economic growth has brought unquestionable benefits to developing countries in spite of this it also has increased environmental vulnerability. The most visible impact is increase in CO2 level which is mostly caused by the using the usage of non-renewable sources such as fossils fuels, natural gas, coals etc. As for a country like Pakistan where energy demand is increasing day by day also relying heavily on non-renewable energy sources resulting in deteriorations of natural environment. understanding the relationship between economic growth, environmental quality and the role of renewable energy has become significantly important.

The environmental Kuznets curve (EKC) is the hypothesized inverted u-shaped curve showing relationship between economic growth and environmental quality. The EKC suggests that at early stage of economic growth the environmental quality worsens and after reaching a certain point further economic growth leads to improvements in environmental quality as shown in the figure below. This hypothesis is widely tested but it remains inconclusive especially in case of developing countries.

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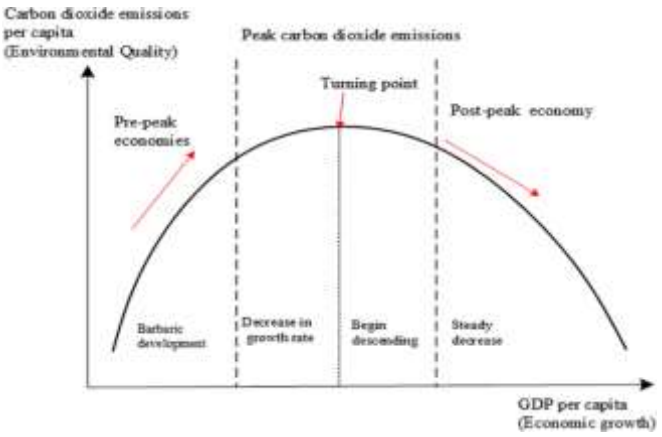

The important limitation of (EKC) is that it often neglects the role of the energy mix. Economic growth does not reduce pollution or improve environmental quality automatically unless it is accompanied by a cleaner energy. Int this context the renewable energy is a key factor in improving environmental quality. Switching from non-renewable energy like fossils fuels and coal to cleaner energy e.g. solar energy and wind energy will reduce the environment degradation. Renewable energy has the potential to lower CO_2 level which is the main factor of environmental degradation.

Pakistan has interesting case for examining this issue. Over the past three-decades Pakistan has experience moderate economic growth along with rising CO_2emissions. Many efforts have been made to increase renewable energy capacity still non-renewable energy source such as fossils fuels still dominated the energy sector so this rise an important question does not Pakistan follows the EKC pattern once the renewable energy consumption is taken into account.

This study addresses this question by testing EKC curve hypothesis for Pakistan and the role of renewable energy consumption on CO2 emissions in Pakistan over the period of time 1992-2021. The main objective of this research is that to test does environmental Kuznets curve hypothesis valid for Pakistan, does inverted u-shaped curve exist and checking how renewable energy consumption impact CO_2 emissions .it will provide policy relevant insight that will support the transition towards cleaner and sustainable growth.

Literature Review

The EKC has been widely used to know the relationship between economic growth and environmental degradation. Grossman and Krueger (1991) introduced this concept they observed an inverted U-shaped relationship between environmental degradation and income. According to them pollution increases in early stages of development but after a certain point it decline when a certain income is reached. This hypothesis has since become a central frame work in environmental economics. However, this hypothesis does not provide insight on how pollution declines and how this happens.

Many Cross-county studies have provided empirical evidence for the EKC hypotheses, Shafik and Bandyopadhyay (1992) tested environmental indicators which included CO_2 emissions across a large sample of countries and found that there exists a non-linear relationship between certain pollution and income. Panayotou (1993) argued that economic growth can improve environmental quality but by appropriated policies. Also, Seldon and song (1994) confirmed EKC pattern for air pollutant and also that turning point for EKC varies across the countries. These studies main focus is existence of EKC

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it lacks the mechanism.

EKC hypothesis is not the same for every country, it heavily depends on many factors. Dinda (2004) in a comprehensive survey concluded that EKC hypothesis can may work for some countries and some pollutants but results depend heavily on model specification, data quality and country characteristics. EKC may shows different pattern for different countries

Recent studies have highlighted the importance of energy consumption patterns in shaping the relationship between economic growth and environmental quality. Ang (2007) found energy consumption is main reason for the CO_2emission in developing countries. Soytas and sari (2009) in their studies found that fossil-duels based energy usage has significantly increases carbon emissions rising concerns about environmental degradation. this study supports that there is need for shifting towards renewable and clean energy. Above studies shows that ignoring energy structure can lead to false result in EKC hypothesis.

Many studies have added renewable energy into EKC framework to check the impact of clean energy on EKC curve. Apergis and Payne (2010) found that renewable energy consumption helps in reducing CO2 emission in OECD countries. Their result suggests that clean energy reduces the positive link between economic growth and emissions.

Further studies supported the role of renewable energy consumption Sadorsky (2009) showed that income growths encourage renewable energy consumption which improves environmental quality. This suggests that shifting towards renewable energy will improves environment quality.

There is limited and inconclusive empirical evidence of EKC hypothesis for Pakistan. Jalil and Mahmud (2009) tested the relation between CO^2 emissions and economic growth in Pakistan and they found that income growth increases emissions in the long run no relation in short run. Their study did not provide clear evidence to support EKC hypothesis. Khan et al (2017) study found partial evidence of an inverted U-shaped relation in EKC but he did not take renewable energy into their analysis. They did not add renewable energy to their analysis so their findings provide us an incomplete view of the economic growth and environmental quality.

Recent studies discussed the role of renewable energy in Pakistan context. Ahmed and Ali (2020) found that renewable energy consumption has negative and significant effect on CO_2 emissions which shows that clean energy can make environmental quality better. This mean that shifting towards renewable energy important to fight against environment degradation.

The existing literature shows that the EKC hypothesis is useful and debated framework for environmental degradation and adopting Renewable energy plays an important role in reducing pollutants (CO_2 emissions) and also in shaping growth-environment relationship. In the case of Pakistan there is insufficient literature and mixed results available for EKC framework with renewable energy. This study will contribute to the literature by highlighting the role of renewable energy into EKC framework for the longer Pakistan from 1991 to 2021 and it will provide evidence on importance of sustainable energy.

Theoretical frame work

This study is based on environmental Kuznets curve (EKC) hypotheses. EKC explains relationship between economic growth and environmental quality, it is an inverted U-shaped curve at early stages it indicates that increase in economic growth leads to more environmental degradation. Mostly carbon dioxide emission (CO2) is taken an indicator

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for the environmental degradation in EKC hypothesis. In developing countries along with economic growth, the demand for energy rises which is mostly obtained by non-renewable energy sources such as fossils fuels. This high usage of non-renewable energy Source cause drastically increases in CO_2 emissions resulting in environmental degradation. As income rises improvements in technology and energy efficiency reduces emissions of pollutants. The outcome mainly depends on the type of energy is used.
Renewable energy plays a significant role in reducing dependency on fossils fuels and coals (non-renewable). Renewable energy usage is expected to lower CO_2 emission and effect the shape of environmental Kuznets curve. In Pakistan's context this study assumes that both economic growth and renewable energy consumption effects the co2 emissions. the framework supports empirical model where CO_2 emissions are explained by economic growths its nonlinear effect and renewable energy consumption.

Methodology

Research design

This research study uses quantitative research design on time series econometric analysis to test the relationship between economic growth and CO_2 emissions with the role of renewable energy on CO_2 emissions in Pakistan. The research is explanatory in nature. The objective is to test EKC hypothesis for Pakistan and check and analyze the effect of renewable energy on CO_2 (proxy for environmental quality) over the time. This analysis uses annual data from 1991 to 2021 this time period was chosen because of the data availability. This time period allows us to study long term relation between the economic growth and environmental performance with the role of renewable energy.
Tools: EViews software will be used as its widely used for time series analysis.

Data source and variables

All the data is used in this research is taken from world bank open data source which is consistence reliable among all variables.

Variables:

dependent variable: annual co2 emissions per capita which is used as proxy for environmental degradation
independent variables:
GDP per capita (constant 2015 us dollars).
GDP per capita in its squared terms.
GDP per capita and its square terms both are used to test the EKC hypothesis and is important to see non-linear relationship between income and co2 emissions.
Renewable energy consumption as percentage of total consumption a key variable to capture the role of energy in reducing co2 emissions.
Control variable: energy use (kg of oil equivalent per capita). Important factor effecting co2 emissions high energy use particularly from fossils fuel leads to higher co2 emissions.
Note: All variables are taken IN natural log form to reduce heteroskedasticity and to interpret its coefficient in term of elasticities.

model specification

Two model are created model 1 and model 2. Model 1 based on EKC framework to test the EKC hypothesis, a positive coefficient of GDP and negative coefficient for gdp^2 support EKC hypothesis. To reduce heteroskedasticity and stabilize the variance of the

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data all variables are transformed into their natural log form.
Model 1: lnCO2t=β0+β1lnGDPCt+β2(lnGDPCt)2+ β3lnENt+et
Model 2: lnCO2t=β0+β1lnGDPCt+β2(lnGDPCt)2+β3lnRENt+β4lnENt+et

Where:
ln CO_2 represents per capita CO_2 emissions
ln GDPC represents GDP per capita
ln $GDPC^2$ is the squared of GDP per capita
ln REN represents renewable energy consumption
ln EN represents energy use (control variable).
t represents specific year of observation 1991 to 2021

Estimation technique
unit root test.

Unit root test is used before estimation to check the stationarity variables to avoid misleading results. Augmented Dickey-Fuller (ADF) unit root test is applied to all the variables. This test tells which estimation technique is most appropriated for estimation. Unit root test is applied check if the variables are stationary at level(I0) or stationary after first difference (I1).

ARDL and ARDL bound test approach

This study uses auto regressive distributed lag (ARDL) techniques to test short and long-run relation between the variables. ARDL model is appropriate when variables are integrated of mix orders and for the small sample size. Fo small sample size like 31 a lower lag is selected the optimal lag length is then determined by Akaike information criterion (AIC).
ARDL bound test is used to check the long run relationship between the variables. F-statistics greater than upper bound value confirms the existence long run relation.
After confirming the cointegration error correction model is will show the speed of adjustment from short run shocks to long run equilibrium.

Cointegration

Ardle bound test is used to check the long run relationship between the variables. If the calculated f-statistic value is higher than the upper bound than the cointegration exists.

Diagnostic and Stability test

Several Diagnostic and stability tests are run to ensure the strength of our findings. Breusch-Godfrey LM test is used to check serial correlation that variables are not corelated over the time. Breusch-Pagan-Godfrey test is used to check problem of heteroskedasticity. For testing that the model is not miss specified Ramsey reset test is used and lastly cumulative sum (CUSUM) and cumulative sum of squares (CUSUMQ) test is used for structural stability of short- and long-run coefficients. These tests make certain that the model is stable.

Analysis and result.
Unit root test for stationarity.

Unit root test was done before the estimation of ARDL model to the stationarity if varainles.in below graph we can see all the variable are non-stationary at level but after 1st difference they become stationary we can check it by seeing p-values, all variables p-values are less than 0.05 so they all become stationary after 1st difference. This confirms

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that ARDL approach is appropriate**.**

Variable	Specification	Level (p-value)	1st Diff (p-value)	Result
LN_CO2	Intercept	0.2116	0.0000	I (1)
LN_GDPC	Intercept	0.9839	0.0041	I (1)
LN_GDPC^2	Intercept	0.9866	0.0044	I (1)
LN_REN	Intercept	0.5934	0.0002	I (1)
LN_EN	Intercept	0.3491	0.0004	I (1)

analysis of model of model 1 and model 2

The detailed analysis and results are obtained by using ARDL estimation technique. two models are run model 1 and model 2. Model 1 is baseline for EKC hypothesis which tests the relationship between co2 emissions and GDP per capita, its square term and energy use, in model 2 renewable energy consumption is added to study the role of it on co2 emissions.

Model 1.

Short run ARDL estimation

To test if standard environmental Kuznets curve (EKC) holds for Pakistan for Pakistan. The ARDL (2,0,0,0) was selected on the basis of Akaike information criterion (AIC).

Table 1: Short-Run ARDL Estimation Model 1for

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_CO2 (-1)	0.2704	0.1648	1.6408	0.1144
LN_CO2 (-2)	0.5314	0.1562	3.4001	0.0025
LN_GDPC	2.6217	3.2044	0.8181	0.4217
LN_GDPC^2	-0.1710	0.2192	-0.7799	0.4434
LN_EN	-0.0626	0.1465	-0.4279	0.6727
C	-9.6299	11.3263	-0.8502	0.4040

After analysis in short run, we find that ln_CO^2 (past emissions) has significantly positive effect on current emissions p value 0.0025 which indicates that environmental pollution has strong momentum effect. Coefficient of GDP per capita is positive 2.62 and coefficient of its squared is negative -0.17 with p value of 0.4217 and 0.4434 respectively means that both are statistically insignificant in short run. This gives us a hint of an inverted U-shaped though it's not conclusive yet.

ARDL Bound test and ECM.

ARDL F bound test was conducted for testing that are the variables move together in long run. Calculated f-statistics 11.4409 is greater than upper bound value 4.306 at 5% significance level this confirm there is cointegration among variables means there is long run relationship between CO_2 emissions, economic growth and energy consumption.

Test Statistic	Value	5% I (0) Bound	5% I (1) Bound	Result
F-statistic	11.4409	3.272	4.306	Cointegrated
ECM (-1)	-0.198100	0.093724	-2.113663	0.0456

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The error correction coefficient is -0.198100 is negative and is significant we can interpret it that the speed of adjustment towards long run equilibrium is 19.8 percent means that 19.8 percent disequilibrium is corrected each year.
Ln GDPC (13.23) while the economy grows initially emissions increases.
Ln $GDPC^2$ (-0.86): the negative indicated that after a certain point further growth in economy may results in reduction of emissions.

Analysis for Model 2
ARDL short -run estimation
In second model testing the effect of ln ren on CO_2 emissions.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_CO2 (-1)	0.2577	0.1645	1.5666	0.1329
LN_CO2 (-2)	0.5187	0.1611	3.2184	0.0043
LN_REN	0.2102	0.2714	0.7746	0.4476
LN_REN (-1)	-0.4267	0.2806	-1.5205	0.1440
LN_EN (-1)	-0.5926	0.3298	-1.7965	0.0875

Coefficient of LN_REN (-1) is -0.4267 is suggesting that increase in share of clean energy reduces emissions while the immediate effect is not significant (p-value 0.14). This model has high r-squared 0.992 suggesting that chosen variables explain around 99.2% of variations on co2 emissions in Pakistan.

5.5. ARDL long-run and bound test
ARDL Bound test was used. The calculated f-statistics 9.05 is greater at 5% significance level than the upper bound 4.223 which again confirms cointegration between variables.

Variable	Coefficient	Std. Error	t-Statistic	Prob.
LN_GDP_C	18.6385	11.8916	1.5673	0.1327
LN_GDP2	-1.2485	0.8289	-1.5063	0.1476
LN_REN	-0.9681	1.3057	-0.7415	0.4670
LN_EN	-1.4274	1.3248	-1.0774	0.2941

In long run LN_REN -0.9681 which is negative means it reduces CO_2 emissions means clean energy consumption is important to make environment quality better in Pakistan. Also, we can notice the EKC model with LN_GDP coefficient 18.63 and LN_GDPC^2 with negative coefficient -1.2485. mean renewable energy does not invalidate the EKC hypothesis but it works it lower the peak of the curve by reducing degradation to the environment.

R-squared for model 1 and model 2
Adjusted R^2 for model 1 is 0.9889 and for model 2 is 0.9890. both models Shows high explanatory power i.e. 98% means that 98 percent variation in co2 emissions is explained by our variables.

DISCUSSION
In model 1 and model 2 coefficients of LN_CO^2 (-2) are significant means that Pakistan's current incremental state is greatly affected by the past energy and industrial practices. I both model LN_GDPC is positive and LN_GDPC^2 is negative which shows evidence of inverted U-shaped curve in EKC but both the LN_GDPC and $LN_GDPC^2$are statistically insignificant means there is no strong evidence to confirm existence EKC for Pakistan in

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this study. And the negative term suggests that structural change in economy can reduce emissions over time.

In model 2 LN_REN and LN_EN coefficients are in negative terms suggesting that both have negative effect on emissions. This lines up with worldwide studies that shifting away from fossils fuel is necessary for separating economic growth from pollution.

Diagnostics Tests

TESTS	**Model 1 Prob**	**Model 2 Prob**	**Conclusion**
Ramsey RESET (Functional Form)	0.1811	0.6224	Correct Specification
Breusch-Pagan-Godfrey (Heteroskedasticity)	0.0889	0.3585	Homoscedastic (Stable)
Breusch-Godfrey serail correlation. (autocorrelation)	0.1545	0.3821	No serious autocorrelation

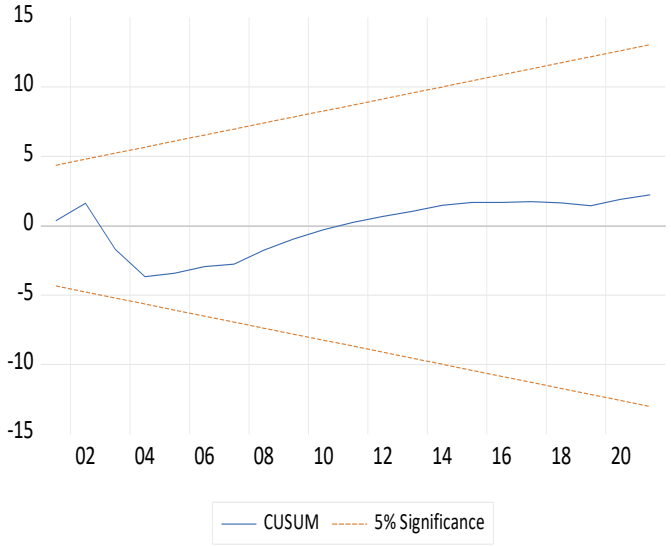
Ramsey reset test: P-values for both models are 0.1811 and 0.6324 indicates that model is correctly specified and it does not omit important variable.

Heteroskedasticity test: P-values 0.0889and 0.3585 for both models is greater than significance level 0.05. this indicates homoskedastic standard errors are reliable.

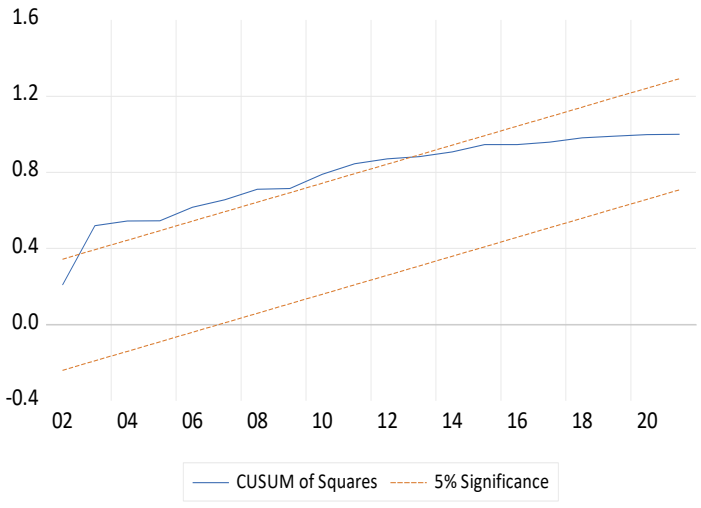
Autocorrelation: P-values for both models are greater than significance level 0.05 indicating there is no autocorrelation issues.

RECRUSIVE STIMATION

The plotted line for CUSUM an CUSUM of square lies within 5% significance for model 1 and model 2. This confirms parameters are constant. This indicates that impact of LN_GDPC and LN_REN did not suffer from sudden shock. The models are table over period of time 1991-2021.



CSUSUM fig model 1



CUSUM of square fig model 1

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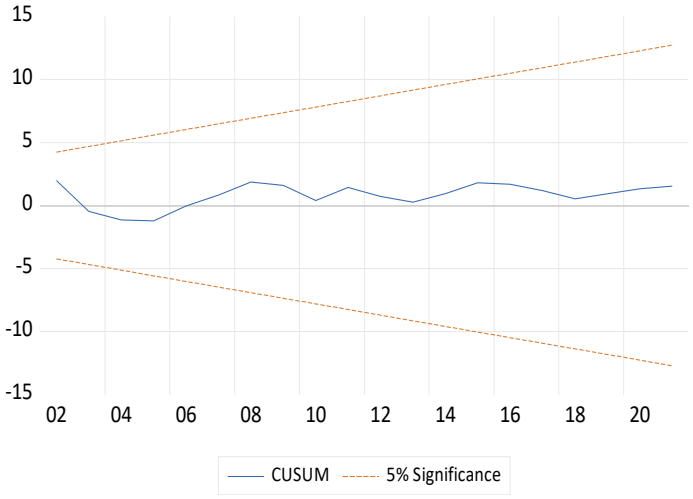
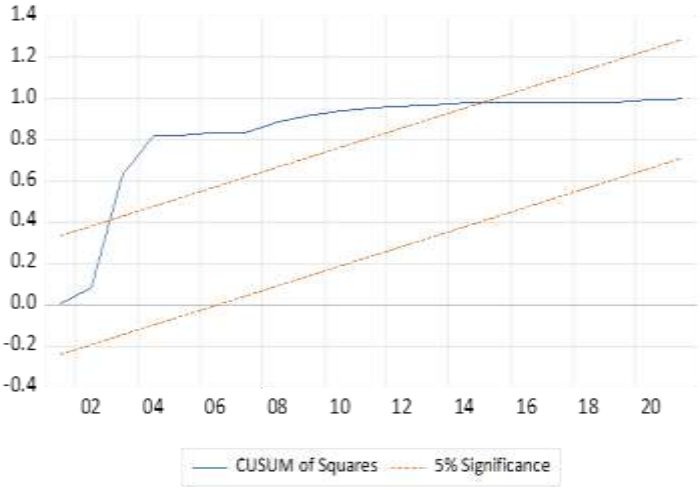


CSUSUM fig model 2



CUSUM of square fig model 2

CONCLUSION.

this study tests the validity of environmental Kuznets curve (EKC) hypothesis for Pakistan and analyze the role of renewable energy consumption on co2 emissions. The study uses annual time series data from1991-2021. ARDL bound test approach was used to study short-Run dynamic and long-Run relationship between economic growth, energy use, renewable energy consumption and environmental degradation.

Then finding provides partial support for EKC hypothesis in Pakistan. In both estimated models GDP per capita shows positive which signs means positive relationship with CO^2 emissions and GDP per capita squared shows negative sign means which negative relationship with co2 emissions. This pattern suggests the existence of nonlinear relationship between economic growth and environmental degradation. This relationship indicates an inverted U-shaped curve. But, the statistical coefficients of these variables suggest that Pakistan is still at increasing part of EKC. Economic growth puts upward pressure on CO^2 emissions. this indicates that economic growth has not reached yet the point where further economic growth improves environmental quality. The lagged emissions coefficient in both the model is large and significant suggest that co2 emissions in Pakistan is highly persistence. This shows Pakistan's past dependency on fossil fuel continues to effect current environments outcomes.

When renewable energy consumption was added in the mode. The long-Run coefficient of renewable energy was negative. This indicates hat increase in usage of renewable energy decreases CO^2emissions in Pakistan. The effect of it in short-run was not statistically significant but in long run the results indicates that renewable energy plays a supportive role in improving environmental quality. Introducing renewable energy does not cancel EKC hypothesis but it just makes the curve less steep.

The finding suggests that Pakistan's current form of economic growth is environmental costly. The expansion of renewable energy can help separate growth from carbon emissions over time. This study highlights that environmental quality is not automatic outcome of economic growth but rather it depends on the energy shift towards clean structure and policies. The result suggests that Pakistan should not depend just on economic growth to address environmental challenges. It should shift toward renewable and clean energy and also by reducing fossil fuels dependency can make EKC curve less steep. Policies to strengthens renewable energy policies will help in sustainable growth while controlling CO^2 emissions.

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The study adds to the existing literature by providing new insights to the EKC hypothesis for Pakistan. It also adds renewable energy consumption in the analysis to help in broad understanding of the relationship. The results highlights that renewable energy is important for achieving long-term sustainable growth.

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