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Evaluating the Impact of Renewable and Non-Renewable Resources on CO2 Emissions and Sustainability

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Abstract

This study analyzes Pakistan's energy system, distinguishing between renewable and non-renewable energy sources. We examine energy production decisions as Pakistan's energy sector faces significant challenges including environmental concerns due to carbon emissions related to nonrenewable energy generation methods using historical data and analytical tools. In essence, we evaluate the relationship between renewable and nonrenewable supplies alongside GDP, trade, and population quantifies changes in land use and counts related carbon emissions. This analysis will provide valuable insights into the environmental consequences of different energy production methods in Pakistan. Regression analysis will be used in the study to demonstrate how the above-mentioned variables affect CO2 emissions using data from 1990 to 2020. Additionally, ARDL test is used for accurate results and cater for unit roots and lag variables. According to previous research, non-renewable energy sources directly correlate with CO2 emissions, but renewable energy sources have a negative effect on CO2 emissions. While we can't be certain of the details until we've crunched the figures, we want to contribute to Pakistan's adoption of wiser energy policies. Consider ways to increase the use of renewable energy, better plan the use of land for sustainable energy projects and reduce carbon emissions in keeping with regional and global environmental objectives. Finding the right course of action for a cleaner, greener energy future is what we're all about in the end. Essentially, climate change, being a global threat, is becoming a serious threat, so to accommodate this concern, a sustainable approach needs to be studied and applied accordingly.

Keywords: Renewable energy, non-renewables, land use, ARDL, sustainability

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1. INTODUCTION

Energy is a fundamental requirement for human development, but sadly, the world's energy reserves vary greatly from nation to nation. The global energy crisis has the greatest impact on Pakistan's social, economic, and environmental well-being of any given problem. This study aims to explore the relationship between various energy sources in terms of cost, yield, and other factors. and examining the impact of energy sources on Pakistan's climate. Pakistan is diverse in that its social, environmental, and climatic traits vary from one area to another. Pakistan is severely affected even though it contributes very little to CO2 emissions. Pakistan's climate change vulnerability is attributed to several factors, including its generally warm climate, location in an area where temperature increases are predicted to be higher than the global average, and the country's mostly arid and semi-arid land area (with 60% receiving less than 250 mm of annual precipitation and 24% receiving between 250 and 500 mm).

Additionally, Pakistan's rivers are primarily fed by the Hindu Kush-Karakoram Himalayan glaciers, which are predicted to recede rapidly due to global warming; finally, Pakistan's primarily agrarian economy makes it particularly vulnerable to climate change. A necessary commodity for modern economies is energy. Consequently, the technologies that are used in its manufacturing and consumption are becoming more and more significant. Energy security and sustainable development are closely related to the availability of a clean, reasonably priced, and consistent supply of energy in a variety of forms. One of Pakistan's biggest concerns is climate change. Pakistan is highly reactive to changes in climate. Pakistan's climate has altered over the past few decades, having a major impact on both the environment and people, much like the rest of South Asia. The Himalayan glaciers are melting due to heat, drought, and other harsh weather, which is raising the water level in the Pakistani river. Pakistan was in fifth place among the nations afflicted by climate change-related extreme weather between 1999 and 2018.

Numerous natural calamities, such as cyclones, floods, droughts, heavy rains, and earthquakes, can occur in Pakistan. Scientific studies indicate that climate change was a major factor in the catastrophic floods of 2022, which directly affected over 30 million people in Pakistan and caused property destruction, fatalities, and home displacement. Climate change is a serious threat to Pakistan's security and economy. With 2 tons of emissions annually per person, Pakistan emits fewer greenhouse gases (GHGs) per person than half of the world average. Pakistan's GHG emissions account for less than 1% of worldwide emissions. In Pakistan, energy-related activities such as burning fuel for heat, powering transportation, and producing electricity accounted for 43% of the country's 408 million tons of CO2 equivalent in GHG emissions in 2015.

Pakistan's energy sector is currently in a transition period, trying to resolve the dual task of supplying growing energy needs and addressing climate change. Given the increasing understanding of the negative environmental impact of energy production, it is increasingly important to determine whether different energy sources have an effect on the amount of CO2 emissions. The present research explores the complex relationship among various elements of Pakistan's power sector with a special emphasis on renewable versus non-renewable resources and their impact on carbon emissions. Some of the previous research has made it very clear that transitioning to the use of renewable energy sources is one way through which we can help curb climate change effects. On the other hand, new forms of green energy like solar, wind, and hydropower appear to be promising alternatives that can be used to mitigate carbon emissions while also promoting environmental sustainability.

In this study, to define the relationship between renewable and non-renewable energy to the emissions of carbon, we run The Augmented Dickey-Fuller (ADF) test assesses whether variables are stationary or non-stationary. P- values below 5% or 10% indicate stationarity. Variables like CO2, FFCp, RECp, and GDP are stationary.To address autocorrelation, we used the Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). A Correlogram is used to visualize autocorrelation portions. The Autoregressive Distributed Lag (ARDL) model is used to analyze relations in time series data. It accommodates non-stationary variables without differencing and aids in policy exploration and forecasting.

Overall, the findings of this study are expected to help policymakers, experts and stakeholders who play a key role in shaping the energy policy in Pakistan. Specifically, by activating the research on the environmental consequences of the various methods of energy production, this study intends to help draft policies that promote expansion of renewables, efficient use of land for sustainable impact energy projects, and carbon dioxide emissions cuts in line with regional and global environmental goals. In conclusion, Given the growing threat of climate change, there has never been more need to prioritize a sustainable approach to energy production. While we may face several challenges in Pakistan’s energy space there are indeed greener and cleaner ways forward. This study overall seeks to provide evidence and recommendations to facilitate decision-making and help generate a more sustainable and reliable energy sector in Pakistan.

2. LITERATURE REVIEW

The world's energy landscape is undergoing a fundamental transition as countries look for ecologically friendly and sustainable solutions to meet their energy needs. Modern countries rely on energy to sustain economic growth, raise living standards, and improve people's quality of life. The regular dependence on non-renewable energy sources, such as coal, natural gas, and fossil fuels, has generated questions about their limited availability and negative environmental effects, particularly the atmospheric release of greenhouse gases like carbon dioxide (CO2). Researchers have repeatedly found that using non-renewable energy sources like fossil fuels (coal, oil, and natural gas) has a negative impact on the climate.

There is a persistent increase in CO2 emissions because of population growth, GDP growth, and industrialization which poses an alarming situation for the country. The repercussions of these increasingly unpleasant activities have ignited a surge in greenhouse gas emissions, which eventually give rise to drastic climate change. Such worrying situations prevailed across the globe (Gallo Cassarino et al., 2018). Since energy demand is rapidly growing, and these energies are extracted from conventional energy sources like fossil fuels, carbon-generated energies, petroleum crude, and many others, there is gradual suffering from the adoption of conventional methods (Nayyar et al., 2014).

On a worldwide basis, it is extremely important to figure out a balance between the need to reduce CO2 emissions and the rising demand for power. The focus of the study, which is on CO2 emissions from Pakistan's energy resources, is thus one of the principal focal points of this study (Raza & Lin, 2019). Global warming, environmental pollution, and energy scarcity are becoming problems for everyone on earth. The increase in global industry and excessive energy use is the main contributor to CO2 emissions. The use of fossil energy has caused climate change by emitting GHGs, including CO2 (Callan et al., 2009) (Wu & Chen, 2017).

The methodology is described as using the Logarithmic Mean Division Index (LMDI) approach. This method can give important insights into the underlying elements and is frequently used to analyze variations in CO2 emissions (Raza & Lin, 2019). The benefit of the LMDI method is that it may be used to break out variations in CO2 emissions. The forecasting of the emissions connected to fossil fuels follows the usage of analysis components (Lin & Ahmad, 2017).

By analyzing the trade-offs between energy supply and priority ecosystem services, Martnez-Martnez's study reveals regions in South-Central Chile that are appropriate for developing renewable energy sources. Limited capacity for biomass, solar, and wind energy as well as medium-to-low capacity for cultural services were found after expert discussions. He concluded that more than half of potential hydropower plants can be positioned in areas with high capacity for regulation and maintenance and medium capacity for service supply. Planning for land-based renewable energy is aided by this information, which also lessens social and environmental tensions (Martínez et al., 2022). In his research, Abraham Deka examined the role that renewable energy, energy efficiency, and forest resources play in halting environmental degradation. He makes use of data from 1990 to 2020 from nations in the European Union. According to the findings, increasing GDP by 1% causes a short-term increase in carbon emissions of 5.62% and a long-term increase of 2.93%. Emissions decreased by 0.03 units and 0.098 units, respectively, by energy efficiency and renewable energy. However, the carbon emissions of European countries are not significantly impacted by forest resources (Deka et al., 2023).

The study by Wang Long looks at the relationship between the use of renewable and non-renewable energy sources, climate change, and economic growth in five developing Asian nations between 1975 and 2020. According to the findings, using renewable energy slows global warming while using non-renewable energy accelerates it. In these nations, urbanization, transportation infrastructure investment, and GDP all contribute to climate change. The study supports the inverted U-shaped EKC hypothesis for developing Asian economies and contends that switching from non-renewable to renewable energy sources is the most effective strategy for mitigating climate change (Wang et al., 2023). In his paper, Muhammad Asif examines the relationship between various energy sources, putting a particular emphasis on the cost, yield, and other factors. It concludes that nuclear energy and renewable energy derived from agricultural waste are the most well-liked sources because of their accessibility and long-term viability. A viable alternative for domestic and industrial energy production and consumption, bioenergy produced from agricultural waste is environmentally friendly and emits less pollution than nuclear energy (Asif et al., 2022). Mudassar Hussain in his study compared the costs and environmental effects of different energy sources, including diesel generators, non-renewable sources, and hybrid solar systems (WAPDA). According to the study, installing hybrid solar systems can cut carbon dioxide emissions by up to 8,446.6 kg of CO2 and 6,131.725 kg over the span of the next twenty-five years. With its low cost per electric unit, renewable energy can pay for its entire installation in just 8 years, saving $4,936.4375. Pakistan's unique geographic characteristics and year-round access to sunlight make it a prime candidate for the effective use of solar energy to cut CO2 emissions and costs (Hussain et al., 2022). In his paper, Irfan Ullah emphasizes how Pakistan's industrialization and energy crisis have made alternative energy sources, CO2 emissions, and health-related issues more prominent. The use of renewable energy sources can satisfy energy needs while promoting environmental health. This study, using data from 1998 to 2017, increased trade volume results in higher CO2 emissions and health care costs. However, renewable energy has a negative correlation with CO2 emissions and health spending, highlighting its significance in improving environmental quality and lowering health spending. The results imply that Pakistan's government requires appropriate policy guidelines for the adoption of renewable energy in the industrial sector (Ullah et al., 2020).

This analysis discovered that a different scenario may assist Pakistan in meeting its emissions reduction goal and provide customers with a 23% yearly savings. The electrical industry in Pakistan is confronted with issues such demand-supply imbalances, frequent power outages, and growing fuel import costs. Pakistan has put in place incentives to produce renewable energy. But now, the sector accounts for almost 63% of the electrical supply. The interconnections between generation technologies, fuel resources, demand, capital investments, CO2 emissions, production costs, and electricity pricing were examined using a dynamic model (Qudrat-Ullah, 2022).

The driving variables for CO2 emissions from power generation in Pakistan from 1990 to 2019 are examined in this study. For measuring CO2 emissions and their correlation with economic development, it makes use of the logarithmic mean Divisia index and Tapio's decoupling indicator. The findings indicate that activity and population are the main causes of increased CO2 emissions, with only a slight buffering in the immediate future. The paper advises encouraging energy-saving technology and changing the industrial structure to reduce CO2 emissions (Lin, 2022).

Finding sustainable energy sources for Pakistan's economy is the primary objective of this research endeavor, which also aims to secure energy supply and create jobs. The report recommends renewable energy technology with low operating and external costs as a way to wrap things up. The Pakistani government ought to encourage technical advancement and renewable energy sources. Pakistan aims to produce green hydrogen utilizing its plentiful renewable energy sources as a sustainable and secure energy source in the future. While geothermal energy has not yet fulfilled its potential for producing hydrogen, wind and biomass are effective renewable sources (Umar et al., 2022).

The study evaluates Pakistan's conventional and renewable energy scenarios and finds that renewable energy only makes up a small portion of the country's overall conventional energy supply. Data on renewable energy installations, activities, projects, planning, and accomplishments of public sector organizations are highlighted. It offers recommendations for efficient resource management and technological application, which is helpful for Pakistan and developing nations (Sheikh, 2010).

For the study of Pakistan, low emission analysis platform (LEAP) software is being used to create scenarios for green energy policies (GEPs). To achieve 100% renewable energy supply by 2050 would be a challenging endeavor or an impossible one, but it is viable with GEP model scenario (Raza et al., 2022). Meanwhile, the dependence of global energy systems (GESs) on fossil fuels is quite high. Due to the energy system's (ES) significant economic expansion over the last century, the world's need on clean energy has increased due to the depletion of fossil fuels, environmental degradation, and geographical imbalance (Afsharzade et al., 2016). Essentially, the Environmental Kuznets Curve (EKC) model holds true for Pakistan in terms of the importance of using renewable and non-renewable energy sources. For the years 1970 to 2012, a variety of econometric methods are employed. Strong evidence is shown by the findings to support the existence of the EKC in Pakistan's situation. The findings indicate that nonrenewable energy use is mostly responsible for boosting carbon dioxide emissions, whereas renewable energy plays a significant role in lowering carbon dioxide emissions (Danish et al., 2017).

The influence of carbon dioxide emissions on Pakistan's forestry, agriculture, livestock, energy usage, population expansion, rainfall, and temperature is investigated in this study. According to the findings, agricultural production, livestock, energy consumption, and population expansion have a negative impact on carbon dioxide emissions, whereas forestry output, rainfall, and temperature have a favorable impact. Emissions are negatively impacted by the use of energy. According to the report, Pakistan's government should implement fresh regulations to raise agricultural output and combat climate change by concentrating on industries including forestry, livestock, agriculture, and energy. Pakistan must play a significant part in combating climate change because of its lower greenhouse gas emissions (Abdul et al., 2021).

Due to a shortage of fossil fuel resources and struggling economy, Pakistan is experiencing an energy crisis. The nation has to enhance its domestic energy resources, such as hydropower, solar power, and wind power, to meet this. The high solar insulation of the nation may be used to produce power as well as other things like solar water heaters and cookers. The paper covers the current state and prospects of solar energy consumption in Pakistan, emphasizing the contribution of R&D organizations to the advancement of solar technology (Umar K Mirza, 2003). The author uses spatial-temporal decomposition data from 2006 to 2016 to examine Pakistan's performance in energy saving and CO2 emissions reduction. The findings indicate that while the GDP gap impact is still below average, the industry sector's economic efficiency and energy consumption efficiency are both above average. While the service sector exhibits a range of results, the agriculture sector performs averagely in terms of structure and intensity impacts (Muhammad Azam, 2021).

3. DATA AND VARIABLES

This study uses data from a variety of credible sources, including the World Bank, the Pakistan Bureau of Statistics, and surveys like the Household Income Consumption Survey. Energy-related data is gathered from a variety of sources, including the Ministry of Energy's yearly reports and the Pakistan Energy Information Portal (PEIP), an online resource created by the Pakistani government. PEIP provides detailed information about energy reserves, production, consumption, and renewable energy sources. Additional data from prestigious international organizations such as the International Energy Agency (IEA) and the United Nations Environment Program (UNEP) enhances the analysis, providing a more comprehensive view of global energy trends. In addition, insights from academic research papers and industry publications are used to provide a more in-depth understanding of various aspects of Pakistan's energy sector. This comprehensive approach ensures a complete assessment of Pakistan's energy dynamics, which aids in comprehending the country's energy issues and potential. Our study is based on the time series data from the year 1980 to 2020. Table 1 indicates key parameters such as mean, median, and standard deviation for the variables under consideration.

Table 1 : Descriptive Statistics

Variables	Description	Mean	Median	Standard Deviation
CO_2	Level of Carbon- di-Oxide (Total CO2 Emissions) in Pakistan	5.02	4.80	4.96
FFCP	Fossil fuel Consumption (Growth rate)	1.05	0.65	2.05
Forest	Forestation (Growth rate of plantation)	5.87	5.85	0.64
GDP	GDP Growth rate	4.73	4.46	2.26
Pollution	Growth rate of pollution in Pakistan	2.63	2.63	0.83
RECP	Renewable energy consumption (Growth Rate)	0.19	-0.40	3.82
Trade	Trade as a percent of GDP	31.49	32.41	4.45

4. MODEL SPECIFICATION AND METHODOLOGY

This paper uses different techniques to reach the final outcomes. Initially we use Augmented Dickey–Fuller test (ADF) tests to distinguish between stationary and non-stationary variables. we will also use Autocorrelation Function (ACF) and Partial Autocorrelation Function (PACF). In time series analysis, the ACF and PACF are critical for understanding the temporal connections within a dataset. The ACF calculates the correlation between a time series and its lagged variants, demonstrating the level of self-similarity at various time lags. It helps in the identification of autocorrelation patterns, revealing how previous values influence current ones (Time Series, Ahmed, 2023). In contrast, the PACF quantifies the direct link between observations at various lags, removing the effects of intervening variables. This makes it valuable for determining the direct influence of previous data on current ones, which helps to identify the right lag structure for time series models such as the Autoregressive Distributed Lag (ARDL) model in econometrics. Analysts can detect the presence of autocorrelation and partial autocorrelation by examining ACF and PACF plots, which aids in model selection and diagnostic procedures to ensure robust analysis of time series data (Ahmed, 2023).

As discussed earlier we have mixed variables in our model, therefore we will use Autoregressive Distributed Lag (ARDL) model to carry out our analysis. The Autoregressive Distributed Lag (ARDL) model is a strong econometric method widely used for analyzing the interactions between variables in time series data. It combines autoregressive (AR) and distributed lag (DL) models to investigate both short- and long-term dynamics among variables. This model may accommodate a wide range of data kinds and relationships, including non-stationary variables and mixed frequencies, without the need for differencing. It captures dynamic interactions by integrating lagged variable values, making it appropriate for analyzing economic time series with non-stationary behavior. Furthermore, the ARDL model supports causal analysis, allowing for the exploration of directional relationships and their magnitudes using model coefficients. The ARDL model is widely used in policy research and forecasting to examine the impact of policy changes or external shocks on economic variables. Overall, the ARDL model emerges as a versatile and necessary econometric tool, recognized for its capacity to reveal complex linkages and dynamics within time series data, particularly in economic and financial research (What Is ARDL Model | IGI Global).

In ARDL modelling, researchers frequently use varied lag durations for dependent and independent variables. They may also use distinct sets of independent variables in the model. AIC aids in the selection of the ideal ARDL model specification by providing a measure of each specification's relative goodness of fit while also taking into account the model's parameter count (What Is Akaike Information Criterion (AIC)? | Built In.). Lower AIC values suggest a better balance of model fit and complexity. As a result, in ARDL modelling, researchers often choose the specification with the lowest AIC as their preferred model. This helps to avoid overfitting while also ensuring that the model accurately represents the underlying relationships in the data.

4.1. Empirical Model

After doing ADF testing we are going to estimate linear regression equation which is as under:

$$CO_2 = f(GDP, Trade, Pollution, Foreset, RECP, FFCP)$$

We can represent the ARDL model equation as:

$$\begin{aligned} CO_{2t} = \beta_0 + \beta_1 CO_{2t_{-1}} + \beta_2 CO_{2t_{-2}} + \beta_3 CO_{2t_{-3}} + \beta_4 CO_{2t_{-4}} + \beta_5 FFCP_{t_{-1}} \\ + \beta_6 FFCP_{t_{-2}} + \beta_7 FFCP_{t_{-3}} + \beta_8 FFCP_{t_{-4}} + \beta_9 Forest_{t_{-1}} \\ + \beta_{10} Forest_{t-2} + \beta_{11} Forest_{t_{-3}} + \beta_{12} Forest_{t_{-4}} \\ + \beta_{13} GDP_{t_{-1}} + \beta_{14} GDP_{t_{-2}} + \beta_{15} GDP_{t_{-3}} + \beta_{15} GDP_{t_{-4}} \\ + \beta_{16} Pollution_{t_{-1}} + \beta_{17} Pollution_{t_{-2}} + \beta_{18} Pollution_{t_{-3}} \\ + \beta_{19} Pollution_{t_{-4}} + \beta_{20} RECP_{t_{-1}} + \beta_{21} RECP_{t_{-2}} \\ + \beta_{21} RECP_{t_{-3}} + \beta_{22} RECP_{t_{-4}} + \beta_{23} Trade_{t_{-1}} \\ + \beta_{24} Trade_{t_{-2}} + \beta_{25} Trade_{t_{-3}} + \beta_{24} Trade_{t_{-4}} + \epsilon_t \end{aligned}$$

Where:

- CO2t is the level of CO2 emissions at time t (dependent variable).
- FFCp, $Forest_t$, GDP_t, $Pollution_t$, $RECP_t$, and $Trade_t$ are the independent variables at time t.
- β_0, β_1, β_2..., β_{18} are the coefficients to be estimated.
- ϵ_t represents the error term

4.2. Augmented Dickey-Fuller test

In the ADF test we set our null hypotheses that variables have unit root test and hence the are non-stationary. While our alternate hypotheses say that our variables are stationary. We accept or reject our null hypothesis based on the P-values of ADF test. If these are less than the threshold of 5% (0.05) or 10% (0.10) then we reject the null hypothesis and our variables are stationary else, we fail to reject the null hypothesis. Based on the results, we infer from the table that Forest, Trade, and Pollution are non-stationary variables.

Table 2: Augmented Dickey-Fuller Test for Unit Root

Variables	**T-stats**	**P-value**	**Results**
CO2	-5.237673	0.00010	Stationary
FFCp	-6.273512	0.00000	Stationary
Forest	0.042436	0.95650	Non-Stationary
Trade	-1.899565	0.32920	Non-Stationary
RECp	-6.93761	0.00000	Stationary
GDP	-3.413404	0.01630	Stationary
Pollution	-2.425974	0.14140	Non-Stationary

From Table 2 we can infer that we have mixed variables. Some are stationary and some depicts non-stationary pattern. Stationary data is a time series dataset in which statistical features such as mean, variance, and covariance are consistent over time. In other words, the data's behavior shows no major trend or seasonality, and its statistical properties are stable over time periods. Stationary data is essential for many statistical analysis and forecasting models because it allows for accurate forecasts based on past trends. Non-stationary data, on the other hand, shows changes in statistical features over time, which are frequently characterized by trends, seasonality, and irregular fluctuations. Non-stationary data presents issues for analysis and forecasting since the underlying patterns might shift unexpectedly, making it impossible to draw meaningful conclusions or make accurate forecasts.

4.3. Regression Analysis

Table 3 represents the linear regression model of our variables. We can infer from the table that *RECp*, FFCp and Trade variable are insignificant. R-squared of this model is also very less equal to 0.447 which means only 44.7 percent of the variation in dependent variable is explained by the given independent variables.

Table 3: Regression Model Estimation Results

Variables	**CO_2 (Dependent variable)**
GDP	0.706*
	(0.358)
Trade	-0.244
	(0.183)
Pollution	-4.092*
	(2.217)
Forest	7.427**
	(3.298)
RECP	-0.183
	(0.170)
FFCP	0.446
	(0.355)
Constant	-23.93
	(12.02)
Observations	41
R-squared	0.448

*** p<0.01, ** p<0.05, * p<0.1

4.4. Autocorrelation:

A Correlogram, also known as an autocorrelation plot or autocorrelation function plot, depicts the autocorrelation function (ACF) of a time series. It displays the correlation coefficients between the observations of a time series and their lagged values at various time intervals. With the x-axis representing lag values and the y-axis indicating correlation coefficients, each bar or point on the figure represents the autocorrelation coefficient at a certain lag. By evaluating the patterns and magnitudes of these coefficients, analysts can detect the presence of autocorrelation in the data, which aids in the discovery of underlying temporal structures such as seasonality or trends. Correlogram are useful tools in time series analysis, assisting with model selection and diagnostics by revealing temporal correlations within the data. Correlogram of variables CO2, FFCP, Forest and Pollution is represented below. For other variables see Appendix Table 1.

4.5. ARDL Model

As we have mixed variables, we will use the ARDL model. We used Akaike Information Criteria to identify the best model. The Akaike Information Criterion (AIC) is a statistical measure used to pick a model from a set of candidates. It balances the model's goodness of fit against its complexity, penalizing too complicated models. In the context of the Autoregressive Distributed Lag (ARDL) model, AIC can be used to compare different model specifications, such as lag lengths or variable inclusion.

Table 4 displays the results of the ARDL model. The interpretation is as follows. The R-squared value in this model is 0.97, indicating that the independent variable accounts for 97 percent of the variation in the dependent variable. The consumption of renewable and nonrenewable energy sources has a significant impact on Pakistan's CO_2 levels. Aside from this, other variables have a substantial impact on the CO_2 level in Pakistan.

The variable of Fossil fuel consumption (FFCP) has a p-value equal to 0.06 which is less than 0.1. This implies that FFCP is significant at the level of 10 percent, and it shows that if growth rate of consumptions of fossil fuels such as Coal, oil, and natural gas increases then carbon dioxide growth rate increases by 0.69 units. Whereas if rate of plantation (variable Forest) has a p-value equal to 0.04 which is also lower than 0.10 which means at the significant level of 10 percent if Forest increases then it would result a decrease of 64.49 units in the carbon dioxide growth rate. GDP also affects the carbon dioxide growth rate. Our analysis shows that if GDP increases then carbon dioxide growth rate also increases by 0.06 units at the significant level of 5 percent. Pollution and trade have a positive effect on carbon dioxide growth rate at the significant level of 10 percent and 5 percent respectively. When Pollution and trade increases then carbon dioxide growth rate also increases by 14.37 and 1.03 units respectively. Lastly, if rate of consumption of renewable energy sources (RECP) increases then carbon dioxide growth rate decreases by 0.68 units at the significant level of 5 percent because p-value of RECP is 0.01 which is less than the threshold of 0.05.

The ARDL model helps us understand how various factors influence the amount of CO2 in Pakistan's atmosphere. Consider CO2 to be the undesirable byproduct of burning coal, oil, and gas. When we burn these things for energy, we emit CO2 into the atmosphere, which is bad for the environment. The model tells us that 97 percent of the time, the amount of CO2 in the air is explained by things like how much energy we consume and other variables. One major factor influencing CO2 levels is the fuels we use for energy, such as coal, oil, and gas. When we utilize more of these, CO2 levels rise. However, planting additional trees (known as forestation) can reduce CO2 levels. Trees are nature's cleansers, taking up CO2 and purifying the air for us. So, planting more trees helps to reduce CO2 levels in the air.

Another factor influencing CO2 levels is a country's gross domestic product (GDP). When a country's GDP rises, it usually signifies that people are purchasing and utilizing more goods, which often takes energy and might result in greater CO2 emissions. So, as GDP rises, so may CO2 levels. Then there is pollution and trade. Pollution occurs when dangerous substances enter the air, such as smoke from factories or exhaust from cars. When there is more pollution, CO2 levels rise. Trade occurs when countries buy and sell goods with one another. When trade increases, more commodities are produced and shipped, which can result in more CO2 being released into the atmosphere. But there's some good news: adopting more renewable energy sources, such as wind or solar power, can help cut CO2 emissions. When we use more renewable energy, we are generating cleaner power that emits less CO2 into the atmosphere. So, according to the model, using more renewable energy can help to reduce CO2 levels. Understanding how these factors influence CO2 levels is critical for making decisions about how we use energy and protect the environment. By planting more trees, using cleaner energy sources, and being careful of our pollution and trade, we can contribute to a healthy planet with cleaner air for everyone to breathe.

Table 4: ARDL Model Results

Variable	Coefficie	Std.	t-	Prob.*
FFCP	0.69	0.34	2.01	0.06
FOREST	-64.96	12.97	-5.01	0.04
GDP	0.06	0.02	0.23	0.41
POLLUTION	14.37	8.46	1.70	0.08
RECP	-0.68	0.07	-9.81	0.01
TRADE	1.03	0.15	6.83	0.02
C	-118.81	14.92	-7.96	0.02
LAGS				
CO2(-1)	-0.49	0.07	-6.64	0.02
CO2(-2)	-0.17	0.05	-3.46	0.07
CO2(-3)	0.08	0.12	0.67	0.57
CO2(-4)	-0.56	0.13	-4.46	0.05
FFCP(-1)	0.18	0.24	0.77	0.52
FFCP(-2)	1.86	0.22	8.33	0.01
FFCP(-3)	1.81	0.22	8.08	0.02
FOREST(-1)	-16.50	14.61	-1.13	0.38
FOREST(-2)	112.26	13.94	8.05	0.02
FOREST(-3)	-60.81	7.63	-7.97	0.02
GDP(-1)	0.01	0.22	0.05	0.96
GDP(-2)	0.46	0.23	2.05	0.18
GDP(-3)	-1.83	0.27	-6.84	0.02
GDP(-4)	0.90	0.20	4.41	0.05
POLLUTION(-	-3.86	2.13	-1.81	0.21
POLLUTION(-	-9.10	2.19	-4.16	0.05
POLLUTION(-	7.19	2.03	3.55	0.07
POLLUTION(-	-9.02	1.24	-7.28	0.02
RECP(-1)	-0.13	0.05	-2.42	0.14
RECP(-2)	-0.07	0.06	-1.12	0.38
RECP(-3)	0.13	0.07	1.79	0.21
RECP(-4)	0.29	0.06	4.88	0.04
TRADE(-1)	0.25	0.11	2.26	0.15
TRADE(-2)	-0.03	0.12	-0.23	0.84
TRADE(-3)	0.05	0.13	0.39	0.73
TRADE(-4)	-0.65	0.14	-4.80	0.04
R-squared	0.97			
F-stats	83.94			

5. CONCLUSION

In conclusion, since the result adheres to the R-squared value in the model stands at 0.97, indicating a strong correlation where 97 percent of the variance in Pakistan's CO2 levels can be explained by various factors, primarily energy consumption. Fossil fuel consumption, with a p-value of 0.06, shows significance at the 10 percent level, meaning an increase in fossil fuel usage leads to a corresponding rise in CO2 emissions. Conversely, variables like plantation (p-value of 0.04) and consumption of renewable energy sources (p-value of 0.01) exhibit significance at varying levels, demonstrating their potential to reduce CO2 levels. The ARDL model helps elucidate the complex relationship between energy consumption, economic variables like GDP, and environmental factors like pollution and trade, highlighting avenues for mitigating CO2 emissions. Through measures such as increasing forestation and transitioning to renewable energy sources, Pakistan can work towards curbing CO2 levels, thus contributing to environmental sustainability. to adequately respond to the challenges of climate change and make a transition to a more sustainable energy sector, Pakistan should implement the following set of policy measures:

Firstly, the country should develop a strategy that would prioritize the targeted support of investments into renewable forms of energy. In particular, the country should stimulate investments in solar, wind, or new hydropower plants through a combination of tax breaks, subsidies, and improved regulatory circumstances. Meanwhile, the country should gradually remove the subsidies from such energy sources as coal or oil to make them more expensive and ease the market’s transition towards cheaper forms of energy.

Equally important, Pakistan must establish comprehensive renewable energy policies that have challenging goals for the production and utilization of renewable energy; policies that are robust enough to explain how it would increase the amount of power generated from this source in overall national energy mix and facilitate its integration into national grid. Additionally, Pakistan should focus on investments in research and development (R&D) programs aiming at improving efficiency, cost effectiveness as well as quality of renewable energy technologies. Such support includes development of innovative solutions for storing electrical energies, technologies for connecting grids with these sources as well as specific types of renewable systems that match geographical attributes and weather patterns unique to Pakistan.

Pakistan has good solar insulation and abundant solar resources, making it ideal for both PV and thermal power uses. Solar radiation is most concentrated in the South, Quetta Valley, and Central Punjab. The Annual Direct Normal Solar Radiation for CSP in Balochistan ranges from 7 to 7.5 KWh/m2/day in some areas and 6.5 to 7 KWh/m2/day others.

Pakistan is developing solar power projects in Azad Kashmir, Punjab, Sindh, and Balochistan. The program is being developed by the International Renewable Energy Agency, China and Pakistan's private sector. Pakistan aims to increase renewable energy us by 5% (approx. 10,000 MW) by 2030. Additionally, 10% of diesel fuel will be replaced with biodiesel by 2025(see appendix figure 1). A GIS wind speed map of 100 meters including wind measurement stations. The data clearly shows that Sindh and Baluchistan have more wind potential than other provinces. According to Harijan (2008), Pakistan has around 346 GW of gross wind energy resources available. According to an assessment conducted by the Pakistan Metrological Department (PMD), the Sindh-Gharo Wind Corridor has a vast wind power potential of approximately 44 GW, of which 11 GW is exploitable and may be connected to the grid (see appendix figure 2).

Additionally, for hydropower, Pakistan's current installed capacity is approximately 19,845 MW, with hydroelectric power accounting for roughly 20%. Much of the remainder is thermal, powered primarily by petrol and oil. According to a 2006 US Department of Energy analysis, the country's per capita energy consumption is predicted to be 14 million Btu, which is almost the same as India's but a fraction of other industrializing economies in the region such as Thailand and Malaysia. Furthermore, Pakistani government should also establish capacity building and workforce development programs for the locals where people of areas could be trained in skills needed for participating in solar energy development. For instance, training in forms of technicians and engineers as well as policy makers to assist them in the planning, installation and undertaking required maintenance of solar energy system throughout Pakistan would be good choice (see Appendix figure 3).

To sum up, by following this policy recommendation, Pakistan can certainly decrease the carbon emission and dependence on fossil fuels which are the major causes for the current energy insecurity. This will also lead to a sustainable energy future to maintain environmental security and improved energy security for coming generations.

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