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THE ROLE OF FOREIGN DIRECT INVESTMENT IN ENVIRONMENTAL DEGRADATION IN PAKISTAN: AN EMPIRICAL ANALYSIS BY USING THE ARDL TECHNIQUE ON TIME SERIES DATA

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ABSTRACT

The study explores how FDI and GDP impact the degradation of the environment in Pakistan. This research applied the ARDL technique to analyze the independent variables' short-run and long-run impact on the dependent variable. Data has been collected from WDI for 25 years. Research results show that energy use together with GDP expansion, urbanization, and trade activities, produce negative impacts on carbon emissions during short periods. The research shows that emissions were significantly negatively impacted by GDP growth and trade in the long-term period alone. Financial development in combination with foreign direct investment (FDI) provides short-term as well as long-term reductions to environmental pollution. The positive effect of innovation exists throughout both short-run and long-run periods as measured by carbon emissions. The prediction part from the present matches the projection for the far future. Research shows innovation produces only minimal yet beneficial effects on carbon emission, which become evident equally in the short-run and long-run perspectives. This study could benefit from learning valuable insights and policy recommendations by evaluating Pakistan's development situation with other nations, which share parallel urbanization and industrialization trends.

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INTRODUCTION

The management of environmental degradation stands as a difficult challenge for industrialized nations when they attempt to create effective natural resource policies. The excessive emission of greenhouse gases leads to substantial environmental damage for both industrialized and non-industrialized nations, resulting in worldwide disturbances (Singh and Singh, 2016). The main environmental concern for states that generate greenhouse gases stems from environmental degradation because of its global effects. The environment collapses rapidly throughout the planet, triggering devastation in all its corners. The energy and resource economy expansion of nations shapes this pattern, and their economic development through energy and natural resource usage leads to higher greenhouse gas releases. The pattern is pushed forward by increasing amounts of greenhouse gas emissions. The environment suffers its worst damage from greenhouse gases that develop from carbon dioxide emissions. Research by Hanif (2018a) confirms that carbon dioxide emissions generate greenhouse gas emissions. The researchers evaluated the energy sector's relationship with the expanding GDP of Pakistan (Hanif, 2018b). The study demonstrates that energy production increases led to Pakistan achieving economic expansion. The investigation employed panel error correction models on 19 developing and developed country data points according to Apergis and Payne (2010), The research included both developing nations and developed countries among its analyzed entities. Higher GDP levels and elevated energy consumption decreased carbon dioxide emissions, based on the collected data. Essential greenhouse gas emissions have recorded a continuous increase worldwide since 1990, according to Gowrisankar et al. (2022).

Modern-era energy resources coupled with behavioral patterns of leading nations serve as the main reasons for greenhouse gas emissions in the atmosphere. A spectacular economic expansion of major developing nations like China, Brazil, and South Africa along with Russia, and Turkey. As a result the increased atmospheric concentrations of greenhouse gas emissions in Pakistan. Environmental deterioration represents an essential challenge that new nations demand their leaders to handle during this period (Filonchyk et al., 2024).

This research revealed that rising carbon dioxide releases directly follow an increase in worldwide economic production. The EKC assumption holds true in 43 developing economies based on research conducted by Narayan and Narayan (2010). A thirty-five percent increase in environmental decline accelerated the slowdown of economic growth in emerging economies. Narayan et al. 2016) analyzed to establish which variables between Indian commercial openness, energy consumption, and economic growth determined CO2 emission rates (2020). The study confirmed that environmental degradation increased due to rising patterns of both commercial globalization and energy utilization. The implementation of free trade systems leads to faster economic development but generates both increased energy demands and it produces detrimental effects on local environments. Expanding on the relation between CO2 increases and growing energy use and GDP the research made use of Granger Causality analysis methodology (Soytas et al., 2001). During the examined period

measurement data demonstrated that US CO2 emissions increased due to population growth despite economic expansion not influencing this data pattern. The rising speed of environmental degradation throughout every stage of economic activity requires permanent sustainable solutions to resolve these issues. The relationship between rising GDP and increased CO2 emissions output was studied by Pao and Tsai (2010) .The economy's growth results in decreased CO2 emissions but the consequent increase of energy use triggers further gas emission levels. Kasman and Duman (2015) investigated the connection between GDP growth and its impact on environmental deterioration and energy consumption from 1992 to 2010. Two main elements that trigger CO2 emissions exist as energy usage and economic advancement.

Policy makers should combine financial development and FDI inflow data to implement incentives for green technology research which leads to decreased environmental damage and reduced greenhouse gas emissions. Scientists are working on removing obstacles in environmental degradation investigations by analyzing monetary obstacles and knowledge gaps regarding the significance of the matter. The examination aims to identify approaches for sustainable investments that aid renewable energy development and clean transportation solutions initiation. The selected solutions will help create a low-carbon economy framework. The study achieves its special significance by combining new data collection methods and analytical approaches together with theoretical frameworks which generate a whole picture of SDG 13 development while pinpointing precise target areas. The research discovers important insights regarding policy instruments that drive environmental research improvement and climate change impact reduction thereby supporting initiatives under SDG 13 (Haque et al., 2022).

Shahbaz (2024) evaluated Indonesian economic trends occurred in 2013 and used the autoregressive distributed lag model (ARDL) to measure Indonesian energy utilization together with economic variables and carbon dioxide emission rates. Scientific evidence demonstrates that increasing CO2 emissions led to energy demand increases together with economic development growth. The combination of expanding economies and political liberties functions as the single mechanism able to lower carbon dioxide emissions levels. Balsalobre-Lorente et al. (2018) studied the relationship between CO2 emissions and economic expansion as well as renewable energy use and natural resources development in five European Union member countries. The economy expanded together with increasing carbon dioxide emissions until citizens started using renewable power sources at which point emissions decreased. Harvie and Pahlavani (2007) applied an ARDL model to South Korean data to assess if power consumption boosts economic development.

The research examines how different economic factors influence carbon dioxide emissions across the entire Pakistani territory. The analysis incorporates GDP production data together with commercial rates and financial progress foreign direct investment volume and urban speed and innovation speed results.

Literature Review

Research by Apergis and Payne (2010) demonstrates that the environmental Kuznet curve hypothesis serves to understand the link between carbon dioxide emissions and economic development. The theory demonstrates how increasing economic production fuels rising CO2 emissions which form an inverted letter U shape pattern. Aqeel and Butt (2001) investigated the connection between energy consumption and economic growth through diverse research strategies across different countries. The study was published in 2001. The research was carried out by Aqeel and Butt serving as its authors. The research was conducted by author together with Soytas et al. (2001). The research results became accessible to the public domain in 2001.

The study conducted by Sarkodie and Strezov (2019) employed panel cointegration tests to identify environmental degrading elements in 17 African economies from 1971 to 2013. The researchers focused on understanding the elements that led to environmental decline. Through their empirical study, researchers confirmed that the environmental Kuznets curve exists because increased economic activity leads to environmental degradation across Africa. The environmental Kuznets curve established this relationship. Bekun et al. (2019) employed the PMG ARDL model to analyze four factors including renewable energy consumption and non-renewable energy consumption together with economic growth and natural resources availability on CO2 emissions in EU member states over 1996 to 2014. Bulgaria, Cyprus, Estonia, and Hungary, together with Latvia, Lithuania, Poland, and Romania joined Slovakia and Slovenia to make up the group of analysed countries. The analysis shows that renewable energy consumption decelerates environmental deterioration yet economy expansion, together with non-renewable energy use, accelerates such processes.

The relationship between Sierra Leone's electricity consumption, economic development, and industrial advances was studied by Asumadu-Sarkodie and Owusu (2017)using vector error correction models (VECM) across the 1980 to 2011 period. The evaluation spanned between 1980 to 2011. Research was performed in the 1980 to 2011 period. The research data demonstrates that multiple environmental damage elements exist. Three main causes drive environmental degradation, including electricity consumption, increasing levels of industrial activity, and economic development.

The research of Asumadu-Sarkodie and Owusu (2017) adopted the ARDL bounds testing approach to analyze the cointegrating link between energy consumption and GDP development in Switzerland across 1950-2010. The researcher conducted this analysis to verify if both variables exhibited a positive correlation between them. A long-term relationship exists between Swiss energy usage and its GDP per capita based on research findings (Canning and Pedroni, 2008). Researchers performed this analysis to prove that Common Wealth nations had panel causal links between electricity use and economic growth from 1991 to 2005. Researchers carried out the analysis to prove the existence of panel causal links between electricity consumption and economic development for commonwealth nations from 1991 to 2005. The research was conducted to present evidence of panel causal association. Karanfil and Li, 2015) showed that 160 countries spanning from 1980 to 2010 had linkage patterns between electricity consumption, urbanization, and economic factors by using the Pedroni panel cointegration methodology. The researchers accessed information spanning from 1980 to 2010 to achieve their objective. A total of 160 different factors presented in the empirical results show ambivalent findings. Liu et al. (2016) performed research in Beijing during the period from 1995 to 2014 to analyze the relationship between carbon dioxide emissions relative to economic development. The study results indicate that when the natural environment deteriorates it leads to positive economic growth. Wei et al. (2017) investigated the relationship between CO2 emissions, economic development, capital and labour force versus South Africa's total energy usage through research conducted between 1960 and 2016.

The research results validated the energy-led growth theory as they showed that greater energy consumption produced increased economic expansion. The finding of this relationship made the energy-led growth theory solid and credible. Research by Tamba et al. (2017) employed a VAR model to check the connections between energy consumption and economic growth in Cameroon between 1975 and 2014. The authors studied data that spanned from 1975 through 2014. They studied both the past and present time from 1975 until 2014 within their investigation. The empirical study demonstrates that energy utilization drives economic growth and both factors interact with each other in a two-way relationship. Sarkodie and Strezov (2019) evaluated the core elements of environmental Kuznets and environmental sustainability curves through the analysis of four distinct economies from 1971 to 2013 which employed panel data methodology. The research followed this timeline from 1971 up to 2013. The period from 1971 to 2013 formed the limited time scope. Studies conducted to test this hypothesis confirmed economic development causes environmental degradation only after nations graduate from basic development stages. The environmental sustainability curve concept is supported because energy use together with economic growth directly results in environmental deterioration. The ARDL model helped (Işik et al., 2017) evaluate CO2 emission impacts from Greek variables like economic growth and financial development. The researchers focused on determining how multiple factors influence each other throughout their inquiry. The research indicates that enhanced financial operations together with increased economic output and increased tourism and commerce generation elevate carbon dioxide emission amounts. Tourism and commerce operate as two related industries, which gain economic benefits from rising activity levels. The study conducted by Sarkodie and Strezov (2019) analyzed the link between environmental changes and readiness to adjust based on data from 192 economies through a panel data model. The research dedicated its focus to analyzing these two contributing aspects. Among the investigated countries Aric turned out to be among those experiencing maximum impact from environmental deteriorating factors. The effect applied similarly to various nations across the study period. Mohiuddin et al. (2016) evaluated the connections between CO2 emissions and GDP and energy use across Pakistan from 1971 until 2013 through their VEC model analysis. The analyzed period spanned from 1971 until 2013. The investigation revealed that carbon dioxide emissions show a positive correlation pattern linked to the usage of energy resources. The authors employed vector autoregression (VAR) together with the Johansen cointegration method in their study to assess energy consumption impact on economic expansion. The research shows no evidence that any investigated factors share relationships that would be categorized as causative. When examining greenhouse gas emission processes regarding energy use economic growth and Foreign Direct Investment (Sarkodie and Strezov, 2019) conducted their study. The research utilized panel data analysis for developing economies which started in 1982 and extended through 2016. An analysis of the data confirms that the pollution haven theory operates in practice since energy consumption leads to reduced environmental degradation. The pollution haven theory receives support because of this evidence. A reduction in environmental damage occurs when renewable energy technology combines with foreign direct investment. The analysis of biomass energy consumption in top ten countries by Rehman et al. (2021) focused on understanding this relationship for economic development from 1980-2010. Research results show that biomass energy consumption stimulates economic development positively. The research-produced outcomes enabled scientists to reach this particular conclusion. The analysis by Destek and Sarkodie (2019) showed that the environmental influence on these nations extended strongly during the period from 1971 to 2013. The study evaluated industrialized countries' ecological footprint and these factors through conducted research, which led to this final conclusion. The analysis reveals economic growth follows a U-shaped pattern with respect to ecological footprint data and demonstrates reciprocal causes between these two variables. The connections between financial development and environmental impact persist in two simultaneous directions.

METHODOLOGY

Data Collection

The research period from 1998 to 2023 allows for the evaluation of different economic situations along with energy consumption patterns on carbon dioxide emissions. The analysis used annual time series data Similar to other studies conducted by Awan et al. (2023a), Awan et al. (2023b), and Younas et al. (2023) because these data would not have been attainable without them. Widespread usage of electricity constitutes the total energy use figure in this research and GDP serves as the indicator for economic development. This study analyzed the relationships between EC, FD, and FDI through an evaluation of CO2 emissions as a dependent variable. The following sequence presents the study's variables symbol and their description is presented in Table 1 and the measurement of variables is presented in Table 2. World Bank Indicators supplied CO2, GDP, EC, FD, and FDI data which were coupled with energy consumption information obtained from various issues of Pakistan's economic survey.

Table 1. Descriptions of research variable.

Symbol	Variable Description	Sources
CO2	Environment degradation	WDI
FDI	Foreign Direct Investment	WDI
EC	Energy consumption	WDI
GDP	Economic growth	WDI
FD	Financial Development	WDI

Table 2. Measurement of variables.

Variables	Measurement of Units
CO2	(CO2) emissions excluding LULUCF per capita (t CO2e/capita)
GDP	Per capita income
FDI	Net Inflows
EC	kWH per capita
FD	Domestic Credit (%of GDP)

Theory and Model

Theoretical background

large carbon emissions play a role in the environmental degradation in Pakistan (Altaf et al., 2023). This study is based on a time series model, and the following equation 1 shows the interaction between environmental degradation and its independent variables.

$$CO_2 = f(GDP, EC, FDI, FD) \quad (1)$$

In Equation 1 the GDP donated for the Economic growth of Pakistan, EC is the amount of energy used as electricity consumption, FDI represents foreign direct investment And FD represents the financial development. These variables are taken in log form.

$$\log CO_2 = f(logGDP, logEC, logFDI, logFD) \quad (2)$$

The equation below shows the long-term relationship between variables.

$$CO2_t = \beta 0 + \beta_1 GDP + \beta_2 EC_t + \beta_3 FDI_t + \beta_4 FD_t + \varepsilon_t \quad (3)$$

The log is taken for each variable below.

$$\log CO2_t = \beta 0 + \beta_1 logGDP + \beta_2 logEC_t + \beta_3 logFDI_t + \beta_4 logFD_t + \varepsilon_t \quad (4)$$

RESULTS AND DISCUSSION

Unit Root test

The analyst needs to check data stationarity properties before applying the model to validate its suitability for the task. In the Augmented Dickey-Fuller (ADF) by Cheung and Lai (1995) and Phillips-Perron (PP) by Cheung and Lai (1997), the unit root tests have been executed to check the stability of the data set. When an array lacks a unit root it becomes stationary and this constitutes the null hypothesis. The analysis determines the maximum order of integration through the implementation of an ADF unit root test. A secondary unit root test and the PP test are used to validate the stationary character of parameters because this preliminary unit root test proves unsuitable. The PP test displays resistance to heteroscedasticity and enables its utilization in time series analysis and evaluation of increased complex serial correlations. Weaker distributions about mistakes can also be accommodated by these methods. The stationary status of our variables is verified through a combined Augmented Dickey-fuller test and Philips-perron test. The Equation for the unit root ADF test is given as:

$$\Delta y_t = \mu + \delta y_{t-1} + \beta_t + \sum K \; i = 1 \; di \Delta y_t - i + \epsilon_t \quad (5)$$

The equation for the PP-Test test is below.

$$\Delta y_t = \mu + \delta y_{t-1} + \beta_t + e \quad (6)$$

Cointegration tests

This research examines the GDP and FDI long-term connection with the CO2 Emissio using the ARDL limits test.

ARDL Model

The ARDL model checks the long-term and short-term effects on the dependent variable if the results of unit root tests are mixed at level and 1st difference. Pesaran and Weeks (2001).

$$\Delta \log CO2_t = \beta_0 + \beta_1 \log CO2_{t-i} + \beta_2 \log GDP_{t-i} + \beta_3 \log EC_{t-i} + \beta_4 \log FDI + \beta_5 \log FD_{t-i} + \sum_{i=1}^{p} \beta_1 \; \Delta \log CO2_{t-i} + \sum_{i=1}^{p} \beta_2 \; \Delta \log GDP_{t-i} + \sum_{i=1}^{p} \beta_3 \; \Delta \log EC_{t-i} + \sum_{i=1}^{p} \beta_4 \; \Delta \log FDI_{t-i} + \sum_{i=1}^{p} \beta_5 \Delta \log FD_{t-i} + \varepsilon_t \quad (7)$$

Mechanisms in the long- and short-runs

The ARDL approach serves to analyze both short-term and long-term (Bahmani-Oskooee and Nasir, 2004) coefficients after validating the series stationarity together with the cointegration method. The cointegrating vectors become apparent through the application of the ARDL cointegration method. When only a single cointegrating vector exists the ARDL model for this vector can be transformed into an error corrections model structure. The reparametrized outcome includes both short-term and long-term interrelationships among instrumental variables. The cointegration validation results allow the researcher to apply equation no. 8 to derive both short-run and long-run effects based on the ARDL methods.

Long-run ARDL

$$logCO2_t = \beta_0 + \sum_q i = 1 \; \beta_1 \; logCO2_{t-i} + \sum_q i = 1 \; \beta_2 \; logGDP_{t-i} + \sum_q i = 1 \; \beta_3 \; logEC_{t-i} + \sum_q i = 1 \; \beta_4 \; logFDI_{t-i} + \sum_q i = 1 \; \beta_5 \; logFD_{t-i} + \varepsilon_t \quad (8)$$

Short-run

$$logCO2 = \alpha_0 + \sum_q \mathrm{i} = 1 \; \alpha_1 \; \Delta \log CO2_{t-i} + \sum_q \mathrm{i} = 1 \; \alpha_2 \; \Delta logTA_{t-i} + \sum_q \mathrm{i} = 1 \; \alpha_3 \; \Delta logEC_{t-i} + \sum_q \mathrm{i} = 1 \; \alpha_4 \; \Delta logGDP_{t-i} + \sum_q \mathrm{i} = 1 \; \alpha_4 \; \Delta logTPG_{t-i} + \mu ECT_{t-1} + \varepsilon_t \quad (9)$$

RESULTS AND DISCUSSIONS

Summary statistics of the variables is given in Table 3. The test ADF in Table 4 and PP in Table 5 demonstrates that all variables reject the null hypothesis at the first-difference level, but most variables fail to do so at the level displayed. The team found the results through their investigative process. All study variables show consistency at the I(1) level according to the analysis results. Research confirms that scientists can implement dynamic ARDL models with I(1) order due to these findings.

Table 3. Descriptive analyses.

Variables	CO2	EC	FD	FDI	GDP
Mean	1.344799	4.144559	0.711911	400.3619	0.807074
Median	1.421345	4.396457	0.740619	423.9011	0.848882
Maximum	2.595001	7.546860	0.803939	429.4491	1.718487
Minimum	0.213828	-1.274087	0.619966	312.9655	0.113711
Std. Dev.	0.565607	1.994716	0.050140	39.48159	0.431766
Skewness	-0.072672	-0.583074	-0.590053	-1.200131	0.286486

Kurtosis	2.823431	3.372647	2.379463	2.715610	2.378588
Jarque-Bera	0.054481	1.561218	1.851786	6.085557	0.744219
Probability	0.973127	0.458127	0.396178	0.047702	0.689279
Sum	33.61997	103.6140	17.79776	10009.05	20.17685
Sum Sq. Dev.	7.677883	95.49337	0.060337	37411.10	4.474120
Observations	25	25	25	25	25

Table 4. ADF Unit Root test results.

Variables	I(0)	I(1)
CO2	1.875*	1.942
EC	2.931*	1.531
GDP	1.074	1.511*
FDI	1.221*	1.832*
FD	1.832*	1.866

Table 5. P.P Unit Root Test.

Variables	I(0)	I(1)
CO2	1.001	1.220**
EC	1.322*	1.342
GDP	1.923*	1.582
FDI	2.533	1.735*
FD	1.946*	1.455

F statistics: ARDL Bound Test Cointegration

The research conducted employed a bound test to examine the long-term interrelationships between separate study variables and produced the results in Table 6. The F statistics results indicate that significant cointegration exists between the different variables with at least 5% significance. The analysis results demonstrate cointegration between multiple variables because the significance value exceeded 5%. The computed value of F statistics surpasses the defined upper limit values. The presented analysis demonstrates that this situation holds true.

Results of ARDL

The table's contents appear in Tables 7 and 8. The study shows that CO2 emissions receive beneficial short-term influence based on power consumption levels, yet this positive outcome is insufficient for this research context. The quantity of electricity used in Pakistan directly impacts carbon dioxide emissions levels positively throughout longer periods. The amount of carbon dioxide discharged into the environment increases in direct proportion to power usage levels. How society uses power sources leads to environmental damage across the entire country. Fossil fuels serve as the primary power source in Pakistan, thus they are the core agents harmful to Pakistan's natural environment and the quality of life. Fossil fuels serve as the primary source that generates electricity in Pakistan. The study maintains reliability because evidence shows its results match those of existing scientific studies (Awan et al., 2023b). The research by both authors demonstrated that environmental damage generation corresponds directly to electric power consumption to link the two variables. Each researcher proved that the two variables are linked. Multiple research indicate that the unestablished renewable sectors in these nations are not stopping their countries from accelerating their economic development. The results do not reflect positively on rising nations even though they operate without established renewable sectors. The available solution rests in maintaining conventional thermal energy generation because it remains the key factor that damages our natural environment.

Table 6. F statistics.

F-Bounds Test		Null Hypothesis: No levels of relationship		
Test Statistic	Value	Signif.	I(0)	I(1)
			Asymptotic: n=1000	
F-statistic	4.585153	10%	2.2	3.09
k	6	5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Table 7. ARDL Error Correction Model (Short Run).

Variable	Coefficient	Std. Error	t-Statistic	Prob.
D(CO2(-1))	0.567270	0.143648	3.949022	0.0055
D(CO2(-2))	0.183912	0.126347	1.455612	0.1888
D(EC)	0.162914	0.027279	5.972239	0.0006
D(FD)	-5.209021	3.419212	-1.523457	0.1715
D(FD(-1))	-18.92269	3.299789	-5.734515	0.0007
D(FDI)	-0.018905	0.009191	-2.056971	0.0787
D(FDI(-1))	0.056832	0.014762	3.849979	0.0063
D(GDP)	0.680867	0.117410	5.799055	0.0007
D(GDP(-1))	-1.238441	0.237788	-5.208168	0.0012
CointEq(-1)*	-1.335592	0.193569	-6.899810	0.0002

Table 8. ARDL Long-Run

Variable	Coefficient	Std. Error	t-Statistic	Prob.
EC	0.176296	0.066365	2.656439	0.0326
FD	18.73379	5.107679	3.667770	0.0080
FDI	-0.006160	0.004854	-1.268981	0.2450
GDP	2.024866	0.537817	3.764975	0.0070
C	-12.06647	2.707269	-4.457063	0.0029

Note: EC = CO2 - (0.1763*EC + 18.7338*FD -0.0062*FDI + 2.0249*GDP -12.0665).

Data from Table 5 shows that CO2 emissions to the atmosphere experience only small variations regardless of how energy sources are used for short or long periods. When CO2 emissions decrease by 1% it predicts that energy consumption will rise by 0.16% both in the near term and the long term. The reductions will manifest throughout both the brief period and the extended period. The research conclusions are reliable according to other investigations published by Sarkodie and Strezov (2019) and Awan et al. (2023a). The results of their study demonstrate that excessive extraction of global natural resources for energy generation produces adverse impacts on natural ecosystems and the environment. The expanding economy leads to statistically important negative effects on carbon emission levels. The situation applies when the detected impacts reach substantial levels. A total impact might be one reason that explains these consequences. Research indicates that short-term carbon emission effects from economic growth show no measurable statistical patterns although they do exist during the temporary period. Such negative effects will only manifest during a brief period. The unfavorable effects exist only during brief periods. Economic growth expansion of 1% corresponds to decreased carbon emissions by 2.2% for the long term and 0.6% for the short term based on measured data. The results of this specific study match those discovered in the research examined above. The researchers discovered through their study that economic development leads to significant negative environmental impacts. This relationship holds statistical value. Research conclusions proved this statement correct. The analysis from Table 5 demonstrates that CO2 emissions experience temporary negative effects from international commerce but reveal substantial long-term negative impacts on these emissions. The study demonstrated this result through its obtained data. Focusing on potent results should end up being applied to upcoming periods and existing periods. Previous studies generated different findings for various reasons according to researchers. The expansion of the economic sector demonstrates direct positive effects on carbon emissions at both short-term and long-term periods according to established environment-friendly impacts of growth throughout the period. The results show that both short-term and long-term economic expansion matches exactly with a corresponding rise of one percent in carbon emissions. The relationship exists across the entire time span from short run to long run duration. Research experts studying financial growth describe it as an essential factor that led to the development of energy projects helping both the energy sector and reducing carbon emissions. The research conducted by Mostafaeipour et al. (2022).

The scientific research supports a positive correlation between nation-based Carbon Emission rates and Foreign Direct Investment inflow into the country. The analyzed data indicates that foreign direct investment elevates carbon emissions by 0.01% in both the long-term and short-term duration following a 1% investment surge. Researchers derived these statistics through they found between the two surveyed variables. Multiple studies have demonstrated that when developing nations welcome direct investment into their industrial and energy sectors it causes a rise in their carbon emission levels. Research results in 2017 provided evidence that backed the study findings. Developing countries experience less energy efficiency than developed nations because of their insufficient infrastructure. The positive effects of innovation on carbon emission reduction developed through both temporary and extended periods but proved less substantial than its initial benefits.

The positive impact on carbon emissions created by these long-term effects will require extended time before becoming visible. The study indicates that a single percentage point rise in innovation can result in carbon emission growth reaching 0.06% in the long run and 0.08% in the near term. The entire variation of the dependent variable served as the basis for the observation. This analysis resulted from computing and evaluating the R^2 value according to the description in the previous sentence. This model's credibility is supported by the F statistics' P-value of 0.002 which can be found in the previous sentence. This table presents diagnostic procedure results for your ease of understanding (Table 6). The Breusch Godfrey LM test functioned to study serial correlation problems with this specific model in this particular research project. The additional analysis step was implemented to achieve comprehensive knowledge about the situation. Our model does not demonstrate serial correlation according to the results of this analysis. The multiple conclusions that can be drawn include this one. The Breusch Pagan Godfrey test together with the ARCH test were performed identically for determining the source of heteroscedasticity in order to handle it properly. The obtained estimated model demonstrates no trace of heteroscedasticity per the tests' outcomes. Based on the available evidence, anyone can make this determination without any reluctance. As part of the research evaluation, the Ramsey reset test served as an investigation element to test the accuracy of the proposed ARDL model. The research establishes that the created ARDL model shows appropriate construction.

CONCLUSIONS AND RECOMMENDATIONS

The research presented in this article analyzed the interrelationships between energy consumption growth, economic impacts, and financial development along with environmental degradation in Pakistan. The ARDL model served the authors to investigate both immediate and extended run relationships between measured variables. The model allows researchers to determine both independent variable transformation patterns alongside their effect on the estimated variable. A joint analysis of the selected variables was performed with ADF, and PP unit root tests to determine the presence of stationary issues. The tests functioned to establish whether the tested variables consisted of related interactions. Results from estimated tests demonstrate that the chosen variables exist in I(0) and I(1) stations allowing the usage of dynamic ARDL simulation modeling. The results obtained through these tests determined that researchers reached this conclusion. The examination of heteroscedasticity and autocorrelation issues in our study

depended on different diagnostic approaches until we reached the fundamental diagnosis.

The positive relationship between financial development and direct foreign investment impacts carbon emissions strongly during both short-term and long-term periods. Scientific data shows a positive correlation between these factors whether observed in short-term periods or extended timeframes. The prediction part from the present matches the projection for the far future. Research shows innovation produces only minimal yet beneficial effects on carbon emission which become evident equally in short-term and long-term perspectives.

Future Directions

Future studies examining relationships between energy use economic development and ecological damage in Pakistan should focus on essential fields of investigation. Extending the analysis window beyond 2023 will enable researchers to observe better long-term patterns since recent economic changes and policy modifications require consideration. Research into carbon mitigation strategies should include a new perspective by examining variables that evaluate renewable energy acceptance together with official environmental regulations along with energy-efficient technologies. The identification of location-specific policies requires thirdly the use of alternative econometric models that incorporate regional data analysis within Pakistan. A study of the specific industry sources responsible for carbon emissions between transportation systems and residential power consumption would enhance knowledge of economic growth effects on environmental protection. Future research should examine how Pakistan's environmental outcomes respond to its economic connectivity with the rest of the world together with supply chain operations and international trading pacts. Analyzing both behavioral and socio-political aspects which encompass public understanding and monitoring agencies would establish a complete framework for sustainable development planning. The study could benefit from learning valuable insights and policy recommendations by evaluating Pakistan's development situation with other nations that share parallel urbanization and industrialization trends.

Limitations

Various constraining factors need recognition within this research project. The time span used for analysis fails to reflect recent economic developments along with environmental modifications and policy changes affecting the connection between energy use and economic activity together with carbon emission patterns. The dynamic ARDL simulation model used in this research might benefit from alternative econometric approaches including panel data analysis and machine learning-based forecasting which would generate new findings regarding variable relationships. Due to its macro-level approach, the study fails to detect specific variations of energy consumption and emission patterns between individual industrial residential and transportation sectors. The paper lacks analysis concerning renewable energy sources and environmental policies thus inhibiting the evaluation of possible mitigation strategies. The research fails to include the evaluation of behavioral and socio-political elements such as regulatory actions and community awareness together with institutional capacity performance that determines sustainability program success rates. The study delivers beneficial information about Pakistan but its results cannot be directly applied to developing nations with unique economic systems and distinct policy standards and energy consumption methods. Future research must expand the current database while investigating multiple variables in addition to testing alternative research approaches to overcome the present limitations in the findings.

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