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Sustainable Development Dilemma: Unraveling the Environmental Impacts of Green Technology and Economic Growth in Pakistan

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ABSTRACT

The objective of this study is to investigate the relationship between environmental CO2 emissions and environmental determinants of green technology, foreign direct investment (FDI), energy efficiency, and economic growth (GDP) in Pakistan. The data uses the period 1995 to 2023. Utilizing the Autoregressive Distributed Lag (ARDL) technique, the results indicate a multifaceted relationship between these variables and environment CO2 Emissions. Green technology has a significantly positive impact on environmental CO2 emissions, through a 1 percent increase and a 1.12 percent decrease in environmental CO2 emissions. Additionally, foreign direct investment (FDI) shows a small but positive impact on environmental CO2 emissions, suggesting that even environmentally intensive investments may have unplanned consequences. Energy efficiency due to its robust effect has a positive impact on the environment's CO2 emissions. Finally, economic growth is found to positively influence environmental CO2 emissions. These results highlight the meaning of targeted policies to exploit the benefits of green technology and economic growth while carefully managing the impacts of foreign direct investment FDI and energy efficiency.

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1. Introduction

Over the past two eras, foreign direct investment (FDI) flows have significantly increased. FDI inflows are extensively expected to foster economic growth in host countries by increasing capital accretion and productivity, which is why many developing economies actively seek to attract more FDI (Ly-My, Le, & Park, 2024; Yasmeen, Zhang, Tao, & Shah, 2023). However, besides its potential to incentivize economic growth, the flow in FDI inflows has generated discussions concerning its potential effects on environmental quality. Studies examining the determinants of environmental quality and focused on income indicators included together energy consumption (EC) and non-energy consumption (Tan & Cao, 2023; F. Wang, Ye, Zeng, & Zhang, 2024). This body of literature checked the strength of the Environmental Kuznets Curve. The EKC theory suggests an inverted U-shape association among environmental pollution and per capita income. Suggesting that as per capita revenue increases, environmental pollution originally rises up to an assured level, after begins to decrease (Pujiati, Yanto, Dwi Handayani, Ridzuan, Borhan, & Shaari, 2023). The usage of energy in the global economy is taken as a primary contributor to environmental quality (Yasmeen et al., 2023). The mission for efficient energy manufacture and green growth has appeared as a noteworthy research area, spurred by the escalating concerns about worldwide environmental effluence and ecological degradation. Environmental problems have extended sensitive visibility and encouraged substantial interest from investigators and consultants in the realm of green technology innovation (Hussain, Anjum, Yousuf, & Ahmad, 2023; Tan & Cao, 2023). In modern corporate landscapes, the significance of green knowledge management (GKM) is documented for its role in making sustainability-focused

services and green products (Chaudhry, Azali, Faheem, & Ali, 2020; Chaudhry, Faheem, Hussain, & Ahmad, 2021; Sahoo, Kumar, & Upadhyay, 2023).

This study attracts motivation from a rising body of knowledge on factors influencing carbon emissions (CO2) decreasing. Key elements of "green technology innovation" (GTI), such as reduced energy amount, enhanced production method effectiveness, and an uptick in sustainable and environmentally friendly goods and services. Identified as crucial motorists for enlightening environmental quality (Chang, Liu, Luo, & Xing, 2023; Faheem, Ali, Farooq, & Hussain, 2023). Nowadays developing nations endeavor to address this global challenge through the progress of green technology. Two significant agreements to protect the environment were prepared in 2015. First is the agenda of 2023, which plans seven SDGs for justifiable growth and there is the Paris Agreement on climate change. Green technology acceptance delivers a win-win condition for together economies by integrating technology into economic processes and sustaining environment by lowering pollution (Amin, Shabbir, Song, Farrukh, Iqbal, & Abbass, 2023; Farooq, Faheem, & Usman, 2020). SDGs primarily emphasize weather transformation issues and object to achieving active outcomes for these multifaceted issues. Technology introduced a comprehensive round to talking global concerns and raising economic growth, which are necessary for attaining sustainable development (Behera & Sethi, 2022). The past few decades have seen amazing advancement in developing nations. They transitioned from the primary sector to industrialization, adopting economic growth and rising living standards (Sethi, Behera, & Sethi, 2024). The risk of environmental deterioration to the human and sustainable growth of all economies around the world is one of the most urgent modern challenges (Kindo, Ouoba, & Kabore, 2023). Foreign direct investment helped in the production of high-technology goods in current few decades. Researchers and officials referred to foreign direct investment (FDI) as the main source of economic growth and included it as a trustworthy source of employment and a source of transferring technology to other nations (Ali et al., 2022). There is a need for efficiency in the use of energy use for temperature revolution. The use of vitality in the world reduced since 2015. It has a optimistic influence on government, business, consumers, and the environment (Chen, Alharthi, Zhang, & Khan, 2024). According to this reasoning, the nations are progressively comprehending the significance of moving the domestic industrial structure to rely on renewable and energy-saving technology. Due to support for the development and use of green technologies, increasing energy consumption, and environmental tasks, the majority of studies believe that financial development can expressively improve energy efficiency. China has therefore proposed several environmental rules and regulations to encourage energy preservation and emissions reduction (Liu, Zhu, Yang, & Wang, 2022; Yu & Tang, 2023).

To achieve economic growth, countries need to use more energy and to increase output, they need over 85% of fossil fuels, which is the cause of 57% of global CO2 emissions. Recently, the chase for economic progress and human well-being came at the cost of extreme carbon dioxide emissions and the rapid use of natural resources (NR) (Singh, Sharma, Radulescu, Balsalobre-Lorente, & Bansal, 2024). As an economic input, energy is a key aspect of environmental thoughts. Energy is undeniably a vital part of a developing economy, but sustainable development is also the highest priority for all economies. To reduce greenhouse gas emissions, countries must take practical steps to decrease environmental damage and maximize resources (Awan & Azam, 2022). Urbanization is a practice that results in the growth of cities as a result of development and economic development. Fluctuations in specialization, labor partition, and social behavior that are unique to urban environments. A demographic factor for urbanization is the thickness of people living in urban areas. According to UN figures from 2018, 55 percent of the world's population lives in urban zones, and expected that in 2050 it will ride and reach 68 percent (Ozturk, Savranlar, Aslan, Al-mulali, & Artan, 2023). To this end, we concluded that is sustainable development attainable in Pakistan. It is expected that the impact of energy efficiency on carbon emission is negative and it’s all due to the level of development. And its impacts are different in developing and developing economies. The transformation of economic get by developed countries may be too much differ from under developed countries. May be this transformation have impact on energy efficiency and other economic factors. The developing economies yet not achieve the renewable energy consumption level (Sinha, 2017). In case of developed nations energy efficiency impact on carbon emission required level not achieved. This provide for underdeveloped nations to make efficient energy policy for better environment. To proposed the influence of dynamism competence with financial development and other economic

indicators chose the theoretical framework and environmental Kuznet curve is the best theory for environmental quality checking (Dinda, 2004; Shahbaz & Sinha, 2019). Thus, the selected model outcomes show the impacts in this context which is basic indication for the developing nations.For this purpose, we select the model in which environment is used as a dependent variable and green technology, FDI, and economic growth are used as independent variables. The aim of this study is to estimate the impact of gross domestic, and foreign direct investment, in green technology on the environment. To proceed further with this study, a literature review of recent studies has been reported in section 2. The theoretic framework is explained in segment 3. Next part 4 explains the data their source measurement and the selected methodology for this study. Results and discussions are discussed in section 5 and the conclusion of the study is in part 6.

2. Literature Review

The growing concern over environmental quality and climate change has led to research focusing on the many factors that influence environmental sustainability. To fulfill economic development wants, people have spent huge quantities of vestige fuels, causing considerable carbon emissions into the air. All these activities contribute to universal warming and ocean level increase (Idroes, Hardi, Hilal, Utami, Noviandy, & Idroes, 2024; Zhao, Dong, Wang, & Dong, 2022). Ali et al. (2022); Xing, Khan, Arshed, and Iqbal (2023) highlighted that the possible negative environmental impact produced by rising CO2 emission is one of the key distresses about foreign direct investment (FDI). Ying Wang, Deng, Zhang, Liu, Yue, and Liu (2022) planned to close this knowledge gap by pooled data from 25 regions in China. The findings showed that energy efficiency in China's various provinces was at a medium-to-low level very negative impact on efficiency of energy. Yasmeen et al. (2023) examined technology, energy efficiency, and technology's influence on the environment in OECD economies. More rent on the situation has a progressive impact on the environment. Sahoo, Kumar, and Upadhyay (2023) used a structure equation model and data from 283 Indian manufacturers. The finding was showed that management and green technology have a positive relation if the use of these two green technology and management as well way. Chang et al. (2023) reported the China economy's green innovation, carbon emission, and environment how to correlate with each other. The findings showed that environmental restrictions have a positive moderating influence on the impact of green knowledge innovation (GKI) on the decrease of CO2 emissions. Hussain et al. (2023); Tan and Cao (2023) analyzed the connection between the two categories of green technical advancements that significantly influence the reduction of CO2. Saqib and Dincă (2024) examined the sustainable development goals with the use of foreign direct investment, economic complexity, environment, and renewable energy.

The results showed that there was a positive relation between variables but a negative impact in the long run. Chandra Voumik and Ridwan (2023) examined the effects of foreign direct investment (FDI), inhabitant expansion, and industry as the aim of this study. According to the findings, industrialization and population increase in Argentina have a negative long-term impact on the ecosystem. Pujiati et al. (2023) investigated the connections in Indonesia between CO2 emissions, energy use, foreign direct investment, and corruption. The results showed that foreign direct investment does not cause environmental damage. Recently, the many harmful caused by the greenhouse effect have gathered international focus, decreasing carbon emissions a global importance. Many countries are now searching for methods to get stability between GDP and environmental quality with green growth emerging as a possible solution for decreasing carbon emissions. Research related to green growth and CO2 is traced back to considerations about the correlation among economic growth (GDP) and CO2. The quick financial growth pays for increased CO2 emissions (Mikayilov, Mukhtarov, Mammadov, & Azizov, 2019; Naseem, Hu, & Mohsin, 2023). Alternatively, examined and suggests that no effect of economic growth (GDP) on carbon emissions (Gorus & Aydin, 2019; Salahuddin & Gow, 2019).Saleem, Zaidi, Ismail, and Goh (2022) founded that growth have positive impact on carbon emissions and decease it in Asian countries from 1995 to 2020. Furthermore, Similarly, Hussain et al. (2023); Zhao et al. (2022) evaluated the affiliation amid growth and finance on CO2 emissions in China from 2005 to 2018 and decided that both growth and green finance (GF) delay environmental quality. Environmental problem is a global problem occurred due to industrial growth and economic growth (Chaudhry et al., 2021; Yan Wang & Shen, 2016). To protect constraint economic development (ED), administration have expressed a sequence of plan tools usually known as environmental regulations (ERs) (Schreck & Wagner, 2017). Frondel, Horbach, and Rennings (2007) highlighted that environmental quality is a significant dynamic force for green inventions.

Environmental quality is an effective source to explain pollution issues coming from the industrial sector (Guo & Wang, 2019). Environmental regulations can control pollution by imposing taxes and regulations on industrial sectors.

To avoid the extra costs linked with environmental pollution, originalities are incentivized to willingly decrease their pollutant emissions (Hájek, Zimmermannová, Helman, & Rozenský, 2019). Porter and Linde (1995) proposed that environmental regulations primarily prevent technological inventions from progressing, but later a period, they begin to encourage it. Ouyang, Li, and Du (2020) showed the influence of environmental quality on technological inventions in manufacturing fields. There are counteracting belongings in a short time, but these properties become compensatory in a long time. Yuan, Ren, and Chen (2017) found the effect of the environment on practical findings is an inverted U-shape in industrial with great and small efficiency, but a U-shape in those with medium efficiency. Brunnermeier and Cohen (2003) demonstrated that increased spending on pollution leads to a higher amount of environmental innovations, with industries that are globally competitive being more likely to develop environmental innovation abilities. Bu, Qiao, and Liu (2020) considered the authorization of ISO 14000 as a voluntary environmental regulation and argued that these rules and regulations enhance innovation in Chinese industry. Turken, Carrillo, and Verter (2020) discussed green technology and emission falling decisions under different types of environmental policies and concluded that firms should invest in green technology emissions to reduce when environmental rules are implemented.

However, some researchers believe that environmental quality only be impacted by some specific conditions. For example, Feng, Wang, Du, Wu, and Wang (2019) analyzed the effect of foreign direct investment (FDI), innovations, and environmental quality in the Chinese economy. Results supporting the Porter hypothesis. Jiang, Wang, and Li (2018); Zheng, Faheem, and Fakhriddinovch Uktamov (2024) identified two types of environmental regulations and found that industrial rules negatively impact innovation performance. Song, Wang, and Sun (2018) verified that staff quality has a beneficial effect on green technology. Fu and Jian (2021) claimed that the environment can inspire corporate innovation in China. Suggested that expenditure is critical for certifying environmental quality effectiveness in developing economies. Borsatto and Amui (2019); Mehmood, Jahanzaib, Faridi, Hussain, and Sehr (2024) noted that the relationship between the environment and green innovation is unreliable. Results revealed the significant impacts of green innovation on the environment (Ang, 2006). Concluded that high energy efficiency means that energy is needed to afford the same energy. David I. Stern (2012) explored that energy efficiency has a decreasing relation with energy demand, which is crucial in contesting climate change. This study aimed to identify energy efficiency improvements and their impact on the environment. Le and Nguyen (2019) investigated the factors influenced by energy conservation and efficiency and showed that energy efficiency has a positive correlation with the environment. Narayan, Liu, and Westerlund (2016); Wei, Ji, Faheem, and Nousheen (2024) found that in the Middle East, income growth positively impacts oil prices. GDP growth has an increasing impact on electricity consumption in countries such as Korea, the UK, Iceland, Finland, Hungary, and the Netherlands. Sadorsky (2009) argued that increasing economic growth and environmental quality have an increasing or positive relationship with renewable energy and oil prices. Faheem, Farooq, Nousheen, and Waheed (2024); Zhang, Zhang, Ding, and Hao (2017) studied the effects of government spending on the emissions of three common pollutants. The results found that government spending directly affects pollution, and has indirect effects. Behera and Sethi (2022) aimed to achieve sustainable development with the use of green technology. The finding showed that Foreign direct investment hurts the environment. This study contributes to the existing literature review by explaining many gaps in the context to understand the association between the environment and key determinants in the context of Pakistan. To increase global focus on the environment a few studies define green technology, economic growth (EG), foreign direct investment (GDP), and energy efficiency impacted the CO2 in underdevelop economies like Pakistan. Recent studies focused on developing economies and those studies did not comprehensively explain the green and non-green technology This research focuses on linking and filling these gaps by using the ARDL model to assess the nuanced and sometimes inconsistent effects of these variables over a broad time.

3. Theoretical Framework

The bonding between economic actions and environmental quality (CO2) has been a crucial point of research, specifically in the framework of sustainable development. This framework explains the environmental impacts on green technology, foreign direct investment, energy efficiency, and economic growth (GDP. Green technology includes a comprehensive range of innovations aimed at reducing environmental impacts and endorsing sustainability. It contains renewable energy technologies, waste management solutions, and innovations in energy efficiency. The diffusion of technology is supported by the Technology Innovation Theory, which suggests that technological advancements can meaningfully decrease environmental degradation (Kammerer, 2009; Mazzucato & Semieniuk, 2018). Foreign direct investment refers to investments that join environmental considerations, concentrating on projects that upkeep sustainable development. These investments are essential for moving green technologies across borders. The Pollution Halo Hypothesis theorizes that multinational corporations can transfer environmentally friendly technologies and practices to host countries, foremost to improve environmental outcomes. The following studies have established that GFDI contributes to reduced emissions and improved environmental (Liu et al., 2022; Pazienza, 2015). Growth relationship with environmental quality is complex and multifaceted. As an economy is enhanced, environmental degradation in start increases, then decreases after success a certain income level. However, this relationship is subject to debate and varies across different contexts and environmental indicators (Grossman & Krueger, 1995; David I Stern, 2004).

4. Econometric Analysis

In this study uses annually data period 1995 to 2023 collect from World Development Indicator (WDI). In this portion explains econometrics methods. The study uses the autoregressive distributive lag (ARDL) method to check the relationship of the proposed variables' impact on the environment (CO2). ARDL technique provides valuable estimates in both short and long periods (Pesaran, Shin, & Smith, 2001). It is appropriate even in a small sample of data (Bulut, 2017). In this model, the ECT term postulates the long-term adjustment period (Alam, 2012). The unit root tests like augmented dicky fuller (ADF) and Philips Perran (PP) results show some variables become stationary at the level (0) and some on 1st difference mixed order of cointegration found. These results lead to the adoption of the ARDL methodology. Diagnostic examinations are exact crucial to test the consistency of findings. For this study uses various tests, including Heteroscedasticity, Ramsey Reset test, Langrage Multiplier, and Jarque Bera Test.

Table 1: Explanation of Variables

Variables	Proxy	Abbreviation	Data Sources
CO2 Emissions	CO2 emissions (kg per 2015 US$ of GDP)	CO2	WDI
Energy Efficiency	GDP per unit of energy use (constant 2017 PPP $)	ENRE	WDI
Foreign Direct Investment	Foreign direct investment, net inflows (Bop, current US$)	FDI	WDI
Green Technology	Renewable energy consumption (% of total final energy consumption)	GTECH	WDI
Economic Growth	GDP (constant 2015 US$)	GDP	WDI

In light of the literature review following models are constructed:

CO2=f (GTECH, FDI, ENRE, GDP)
CO2= Environment (Dependent Variable)
GTECH= Green Technology
FDI= Foreign Direct Investment
ENRE= Energy Efficiency
GDP= Economic Growth

Following is the model specification based on the previous studies,

$$CO2_t = \phi_1 + \phi_2 GTECH_t + \phi_3 FDI_t + \phi_4 ENRE_t + \phi_5 GDP_t + \mu_t$$

Standard theory assumes that in the above model, $\phi_2 > 0$, $\phi_3 > 0$, $\phi_4 > 0$, and $\phi_5 > 0$. The error period is measured to be ordinarily dispersed. The numbers ϕ_2, ϕ_3, ϕ_4, and ϕ_5 are the elasticity of environment concerning the green technology, foreign direct investment (FDI), energy efficiency, and gross domestic product (GDP). The specifications of the ARDL model are as follows:

$$\Delta CO2_t = \alpha_0 + \sum_{i=1}^{l} a_{1i}\Delta CO2_{t-1} + \sum_{i=1}^{p} \alpha_{2i}\Delta GTECH_{t-i} + \sum_{i=1}^{q} \alpha_{3i}\Delta FDI_{t-i} + \sum_{i=1}^{q} \alpha_{4i}\Delta ENRE_{t-i} + \sum_{i=1}^{q} \alpha_{5i}\Delta GDP_{t-i} + \phi\, CO2_{t-1} + \phi_2 GTECH_{t-2} + \phi_3 FDI_{t-3} + \phi_4 ENRE_{t-4} + \phi_5 GDP_{t-5} + \mu_t$$

5. Result and Discussions

This portion of Descriptive statistics results is in the succeeding table 5.1 Shows the value mean CO2 emissions 0.629, green technology 47.454, foreign direct investment 1.91E+09, energy efficiency 9.623, and economic growth 2.32E+11 respectively. The maximum value of the CO2 emissions is 0.703, green technology 51.610, foreign direct investment 5.59E+09, energy efficiency 11.949, and economic growth 3.62E+11respectively. The minimum value of the CO2 emissions is 0.519, green technology 42.100, foreign direct investment 3.08E+08, energy efficiency 7.993, and economic growth 1.36E+11respectively. The standard deviation value of the CO2 emissions is 0.047, green technology 2.526, foreign direct investment 1.41E+09, energy efficiency 1.240, and economic growth 6.80E+10 respectively. The skewness value of the CO2 emissions is -0.635, green technology -0.040, foreign direct investment 1.351, energy efficiency 0.427, and economic growth 0.283 respectively. The kurtosis value of the CO2 emissions is 2.685, green technology 2.618, foreign direct investment 4.396, energy efficiency 1.897, and economic growth 1.950 respectively. The Jarque Bera value of the CO2 emissions is 1.784, green technology 0.158, foreign direct investment 9.646, energy efficiency 2.026, and economic growth 1.482 respectively. The probability value of the CO2 emissions is 0.409, green technology 0.923, foreign direct investment 0.008, energy efficiency 0.363, and economic growth 0.4765 respectively.

Table 2: Descriptive statistics

	CO2	GTECH	FDI	ENRE	GDP
Mean	0.629	47.454	1.91E+09	9.623	2.32E+11
Median	0.642	47.206	1.74E+09	9.281	2.22E+11
Maximum	0.703	51.610	5.59E+09	11.949	3.62E+11
Minimum	0.519	42.100	3.08E+08	7.993	1.36E+11
Std. Dev.	0.047	2.526	1.41E+09	1.240	6.80E+10
Skewness	-0.635	-0.040	1.351888	0.427	0.283253
Kurtosis	2.685	2.618	4.396568	1.897	1.950165
Jarque-Bera	1.784	0.158	9.646670	2.026	1.482378
Probability	0.409	0.923	0.008040	0.363	0.476547
Sum	15.748	1186.352	4.77E+10	240.596	5.81E+12
Dev.	0.053	153.171	4.75E+19	36.922	1.11E+23

In table 2 correlation matrix results explain in correlation we check the impact of variables with each other. Here green technology coefficient is 0.211 which shows a positive but weak correlation with the CO2 emissions. The foreign direct investment (FDI) coefficient with the CO2 emissions is 0.137 and green technology is -0.575 means that it has a positive and weak correlation with the CO2 emissions and green technology. The energy efficiency coefficient is -0.822 with the CO2 emissions, -0.631 with green technology, and 0.158 with foreign direct investment which shows a negative but strong correlation with the CO2 emissions and green technology and a positive but weak correlation with foreign direct investment. The Green Growth coefficient is -0.822 with CO2 emissions, -0.686 with green technology, 0.229 with foreign direct investment, and 0.993 with energy efficiency, which means that there is a negative but solid correlation with the CO2 emissions and green technology and a positive but weak with green foreign direct investment and a strong with energy efficiency.

Table 3: Correlation Matrix

ADF Tests		
Variables	**At level (0)**	**At 1st Diffrence (1)**
CO2	-0.5380	-5.6237
	(0.8669)	(0.0001)
GTECH	-1.8092	-3.5635
	(0.3668)	(0.0152)
FDI	-2.6338	-3.2839
	(0.0009)	(0.0277)
ENRE	2.8891	-5.9747
	(1.000)	(0.0004)
GDP	2.1058	-3.0887
	(0.0098)	(0.0416)
PP Test		
Variable	At level	At 1st Difference
CO2	-0.3049	-5.6556
	(0.9104)	(0.0001)
GTECH	-1.9234	-3.5635
	(0.3166)	(0.0152)
FDI	-2.0255	-3.2839
	(0.0447)	(0.0277)
ENRE	7.6168	-5.2903
	(1.0000)	(0.0003)
GDP	2.5373	-3.0887
	(0.9999)	(0.0416)

Table 4: Unit Root Test Results

	CO2	**GTECH**	**FDI**	**ENRE**	**GDP**
CO2	1				
GTECH	0.211	1			
	(0.309)				
FDI	0.137	-0.575	1		
	(0.511)	(0.002)			
ENRE	-0.846	-0.631	0.158	1	
	(0.000)	(0.000)	(0.448)		
GDP	-0.822	-0.686	0.229	0.993	1
	(0.000)	(0.000)	(0.270)	(0.000)	

Unit root test is applying to check the data stationarity. Data is a time series so we have used ADF and PP tests to check the variables become stationarity CO2 emissions, green technology, energy efficiency, and green growth variables becomes stationary at the level and 1st difference in both ADF and PP test. All variables result diversified order of cointegration. The bound test is an addition of the ARDL test and its estimated value is 3.67, which describe the value of F- statistics is higher than the upper bounds. Its mean long-run cointegration was found in variables.

Table 5: Bound Test

Linear ARDL Technique	**F-Statistic**		**I(0)**	**I(1)**
	3.67	10%	2.2	3.09
		5%	2.56	3.49
		2.5%	2.88	3.87
		1%	3.29	4.37

Sources: Authors' calculations

The long-run outcomes of ARDL show significant insights into the relationship between CO2 emissions and selected variables. The coefficient of green technology is -1.120, showing a statistically substantial impact on CO2 emissions at one percent. This proposed a one percent rise in green technology reduces -1.12 percent in the environment. This shows that green technology plays an important role in the improvement of CO2 emissions in the long run. Greater than one elasticity highlighted the strong impact of green technology on CO2 emissions. The coefficient for foreign direct investment is 0.0191 and statistically significant at 5 percent which shows that a 1 percent increase in foreign direct CO2 emissions of 0.019 percent CO2 emissions will be increased. The positive relationship of foreign direct investment highlighted that some

energy and resource burdens are brought by foreign direct investment. Energy efficiency is significant at a 10 percent level with a negative constant of -0.4293. Suggested that a 1 percent increase in energy efficiency means that 0.43 percent of CO2 emissions will be decreased. The green growth coefficient is 0.566 which is significant at 1 percent. Shows that a 1 percent increase in green growth leads to a 0.57 percent increase in CO2 emissions. There is a positive relationship between green growth and CO2 emissions with the increase in economic growth CO2 emissions will be improved in the long run. Due to better environmental policies investments increased. The constant term (C) is 17.3135 and is highly significant, which suggests a considerable baseline level of CO2 emissions when the other factors are held constant.

Table 6: Long-run Findings

Name Variable	Coefficient	Sd. Err	t-Statistics	Prob.
GTECH	-1.1204***	0.0926	-12.0914	0.0000
FDI	0.0191**	0.0068	2.7891	0.0131
ENRE	-0.4293*	0.2049	-2.0946	0.0525
GDP	0.5669***	0.1003	5.6488	0.0000
C	17.3135***	2.2426	7.7201	0.0000

5.1. Short Run Findings

Short run, results reveal that the green technology coefficient is -1.310 and highly significant at the 1 percent level. The negative coefficient shows that one percent enhance in green technology the CO2 emissions will reduce at -1.31 percent. Greater than 1 elasticity shows the immediate positive impact of green technology on the CO2 emissions in the short run. The foreign direct investment coefficient is 0.0111 but does not statistically significant impact on the environment. This suggests that foreign direct investment does not have an impact on environmental degradation in the short run. The energy efficiency coefficient is -0.502 and it is significant at 5 percent. This shows that 1 percent increase in energy efficiency environmental degradation will decrease by 0.50 percent. The coefficient for green growth is 0.938, which is highly significant at the 1percent. This positive relationship suggests that a 1 percent increase in GDP leads to a 0.94 percent rise in environmental degradation. This aligns with the notion that economic growth in the short term may contribute to better environmental outcomes.

Table 7: Short Run Findings

Variables Name	Coefficients	Sd. Error	t-Statistics	Prob Value
D(GTECH)	-1.3104***	0.1158	-11.3105	0.0000
D(FDI)	0.0111	0.0075	1.4863	0.1566
D(ENRE)	-0.5021**	0.2354	-2.1327	0.0488
D(GDP)	0.938***	0.1676	5.5968	0.0000
CointEq(-1)	-1.1695***	0.0935	-12.4953	0.0000

Note: All variables taking in log forms

5.2. Diagnostic Tests Results

The Diagnostic tests for ARDL technique is presented in table 4.7 explain that the model is statistically good and well specified. R^2 value 0.9363 indicate that 93.63 percent distinction in dependent variable is explore by independent variables. Adjusted R^2 value is 9303 and demonstrate that model is fit. Durbin Watson value is close to 2.1096 and highlighted that there is no autocorrelation in the model. To check the normal distribution uses Jarque Bera test and t-value is 0.6637 and probability value is 0.7175 which is greater than 0.05 threshold value. Suggested that model is normally distributed. LM tests shows that there is no serial correlation with 0.9188 t value and 0.4218 p value which is upper than 0.05. There is no heteroscedasticity in the model check with Hetro test. The value of Hetro t test is 1.4414 and p value is 0.2565 which is greater than 0.05 threshold value. Ramsey test is employ to check the model specification of this study and value t test is 2.1211 and p value is 0.0510 is close to 0.05 threshold value which shows there is no misspecification in the model.

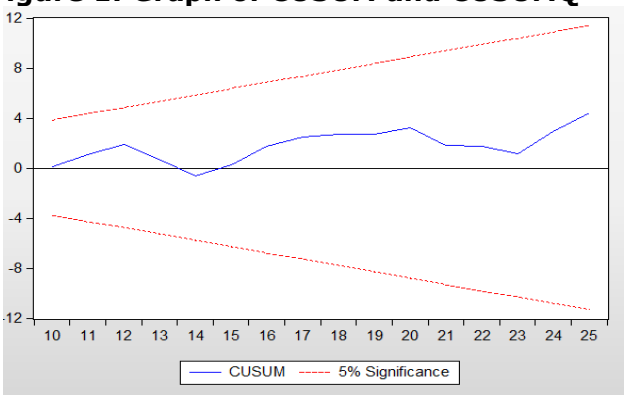
Table 8: Diagnostic Tests Findings

R Square value	0.9363	F.Value=113.407
Adj. R square value	0.9303	D.W=2.109
Jarque Berra Test	0.6637	(0.7175)
LM Test	0.9188	(0.4218)
Hetero Test	1.4414	(0.2565)

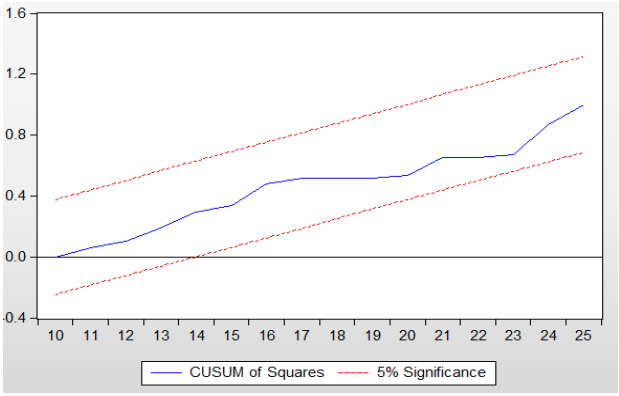
Ramsey Test	2.1211	(0.0510)

Below the figures shows the result of CUSUM and CUSUMQ and it is shows that the model is stable.

Figure 1: Graph of CUSUM and CUSUMQ



CUSUM



CUSUMQ

6. Conclusion

The study provides valuable visions into long-term associations among environmental quality (CO2) and its factors. This paper uses the auto-regressive distributive lag (ARDL) method check the relation among the variables. Time series data taken from 1998 to 2022 from WDI. Green technology occurs as a crucial factor in reducing environmental degradation, highlighting the need for continued innovation and investment in this area. The optimistic influence of economic growth on environment suggests that economic growth can be companionable with environmental sustainability. likely due to the increased resources available for environmental protection and the adoption of cleaner technologies. However, the positive relationship between energy efficiency and environmental degradation raises concerns about the rebound effect, highlighting the need for comprehensive strategies that ensure energy savings translate into real environmental benefits. The small but significant positive impact of FDI on environmental degradation suggests that such investments must be carefully managed to avoid unintended consequences. Based on the results policymakers and government officials provide tax reductions and incentives to individuals and businessmen who adopt green technology, like solar, electric vehicles, and energy-efficient user goods. Strict policies for high-user CO2 emissions industries to adopt cleaner technology. Launch a campaign of awareness in the public and sector on the benefit of green technology. Focus on strict for foreign investors requiring them with national environmental level. Start a project in which international companies must give proof that their investment will contribute to decreasing environmental degradation. In Pakistan maximum positive impact of energy efficiency on decreasing the CO2 government should imply strict energy efficiency for vehicles, and building appliances and promote the practice of energy efficiency with the management system. Implications of economic growth focus on decreasing environmental degradation government should transition growth in to green growth Promote renewable energy resources and push the energy efficiency use in all public and private sectors. Implement the strict environment rules and regulations and focus on industrial sustainability.

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