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Urbanization, Green Finance, and Environmental Sustainability in Pakistan

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ABSTRACT

Sustainable development is a key objective of all countries in recent years. Therefore, accounting for the role of urbanization as essential parts of sustainable development, we have evaluated the impact of green finance, urbanization, GDP, and FD on CO2 emissions for Pakistan from 1983 to 2023. We applied the NARDL technique to examine the asymmetric correspondences between studied variables. The practical observations unveiled a conclusive association between CO2 emission and urbanization in positive shocks, while in negative shocks, urbanization purifies the environment. In terms of green finance and FD, the findings displayed a favorable impact of GF and FD on the environmental quality in Pakistan. GDP showed a positive relationship with CO2 as it enhances CO2 in the long term. In view of the findings, policymakers are suggested to advance rural areas, design planned cities, and encourage green finance to practice eco-friendly projects.

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1. Introduction

Environmental degradation has become a grave threat to human life and economic progress as it adversely affects both of these (Bank & Evaluation, 2016). A clean and healthy environment is fundamental to preserving natural resources, booming an economy, and creating a sustainable community. CO_2 emissions damage the ozone layer and contribute to climate crisis and global warming; lowering CO_2 emissions is essential to preserve the world and attain sustainable development (Farooq, Leong, et al., 2024; Sadiq et al., 2024). Based on this, carbon neutrality and sustainable development have emerged. The EU countries started working on this carbon neutrality objective by implementing strict regulations and establishing the European Green Deal to Zero CO_2 emissions by 2050 (Dam et al., 2024; Pata, Kartal, & Mukhtarov, 2024). Although fossil fuels are the major contributor to CO_2 emissions, governments and policymakers around the world are coming forward to regulate CO_2 emissions and tackle the aftermath of CO_2 (Wang et al., 2021; Wei et al., 2024). Rapid development and increased hydrocarbon deposit in developing countries are responsible for a 50% surge in GHGs. Despite the complete implementation of climate commitment, the world is failing to fulfil the Paris Agreement and escalating the climate risk (OECD, 2021). Over the last few years, the world has experienced rapid growth in urbanization; over 50% of the population is residing in cities (Zhang, 2016). Both the developed and developing countries tend urbanization as it has become a symbol of modernization (Wang et al., 2021). The bond between urbanization and environmental survival is a hot debate nowadays. Since 1947, Pakistan has experienced a rise in urbanization. World reports claim that urbanization in Pakistan has increased from 29% in 1985 to 37% in 2021; this surge in urbanization led to various environmental challenges like air pollution, carbon emissions, and water contamination (Pan et al., 2023). Urban heat island effects force urban areas to contribute to climate change. Several researchers confirm the significant impact of urbanization on CO_2 globally (Sufyanullah, Ahmad, & Sufyan Ali, 2022). Countries with unplanned urbanization causes a rise in natural resources consumption and higher energy consumption (Destek & Ozsoy,

2015). Three theories explain the urbanization environment nexuses. The theories include EMT, ETT, and CCT. The ecological modernization theory claims that environmental degradation is associated with the expansion of the economy. This damage could be minimized by effective and planned urbanization (Azam et al., 2022). Unplanned urbanization leads to many environmental challenges, such as industrial dumps, municipal contaminated material, heavy traffic on roads, and expansion in slums. Moreover, urbanization stimulates industrial production, leading to higher air pollution in the atmosphere (Samreen & Majeed, 2020).

Green finance has become a global phenomenon. As it lowers CO_2 and supports economic growth, countries worldwide are directing their financial resources toward green investment. These green initiatives lead to improved environmental quality and strengthen overall environmental performance (Ping & Shah, 2023). Green finance is considered the best tool among various advanced technologies proposed for environmental sustainability and economic development by providing financial support to companies by funding the purchase of eco-friendly equipment to evolve sustainable technologies (Ping & Shah, 2023). Environmental regulations play a crucial role in lowering CO_2 emissions. Among these regulations, the most effective is green finance, which balances economic growth with ecological sustainability. Green finance reduces CO_2 emissions by encouraging low-carbon initiatives, promoting energy efficiency, and fostering green innovations (Gan & Voda, 2023). Green finance makes it more feasible for companies to adopt eco-friendly initiatives than traditional practices, enabling stakeholders to allocate R&D funds to managing environmental sustainability (Ping & Shah, 2023). Moreover, Green finance supports long-term green investment to promote environmental perseverance and reach sustainable development goals (Tran, 2022; Umar & Safi, 2023). Since the start of the 2000s, FD contributed significantly to shaping economic progress and environmental health. However, still, there is no definitive consensus on the financial development and environment nexus. Many researchers argue that FD makes a significant contribution to environmental sustainability as it facilitates businesses' and consumers' adoption of green technology. Additionally, A strong financial system serves as a catalyst driving efforts to minimize carbon emissions by promoting eco-friendly technologies and practices (Faheem et al., 2024). The existing literature found mixed results about nexus between FD and environmental preservation. Some findings suggest it significantly boost energy efficiency, while others argue it may also increase CO_2 emissions. Financial development may increase economic prosperity and global trade, causing higher CO_2. Yet, it promotes the adoption of green technological practices, ultimately dropping CO_2. More research is required to be conducted to understand its impact on environmental sustainability truly (Wei et al., 2024). Effectively and efficiently, financial systems provide easy access to financial instruments and decrease financial costs, leading to a surge in energy demand for economic activities and thus increasing CO_2 emissions (Salahuddin, Alam, & Ozturk, 2016). Additionally, Financial development promotes R&D to produce environmentally friendly technologies to combat the harmful consequence of GHG emissions (Wang, Wang, & Li, 2022).

GDP is often considered an indicator of the economic progress of a country; countries are categorized as rich or poor based on per capita income. Industrialization is crucial in driving prosperity but at the cost of environmental health as it engages energy in production process (Nousheen, Farooq, & Faheem, 2024). The world is concerned about the relationship between GDP and ecological sustainability. Economic activities are directly connected with energy consumption, which leads to higher CO_2 missions. Since 1990, developing countries have degraded the environment more than developed. As developing countries expand their industries for economic progress and ultimately boost emissions (Farooq, Shah, et al., 2024a; Nousheen, Farooq, & Faheem, 2024). Adopting Clean Energy and eco-friendly technology is imperative to achieve long-term economic prosperity. Economic progress and resource depreciation are directly connected, so economic activities contribute to a parallel escalation in environmental degradation (Farooq, Shah, et al., 2024b). Economic prosperity in impetus industrialization causes natural resource depletion in mining and deforestation and degrades the environment (Faheem et al., 2024; Farooq, Faheem, & Nousheen, 2023a). Additionally, Economic growth has dramatically improved humanity's quality of life and living standards, but it has damaged the environment brutally in terms of climate change and global warming. Economic progress depends mainly on economic activities, which cause CO_2 emissions via energy consumption (Faheem et al., 2024). Current study significantly promotes the existing literature in various ways. The key contributions are stated here: This study utilized the NARDL method instead of the conventional ARDL method. The NARDL helps identify how a rise or decline in urbanization affects CO_2 in Pakistan, which is

often overlooked. Another key contribution is the addition of urbanization, GF and financial development, which often remains unexplored in Pakistan. This study is the first to explore the urbanization-environment sustainability relationship, examining the effect of expanded urbanization on Pakistan's environmental quality. Moreover, the current study's empirical findings offer insightful policy suggestions on how urbanization, green investment, and financial sport can amplify the ecosystem's health. Moreover, these policy suggestions can be helpful for similar emerging economies. The remaining part of the current study is structured as follows: Section 2 reviews the past literature, section 3 represents the Data and Methodology used in this study, section 4 represents the "Empirical Findings," and section 5 describes the conclusion and Policy Suggestions."

2. Literature Review

2.1. Theoretical Linkage

The growing trend of urbanization has prompted the problem of environmental quality and sustainability globally. Plethora of research determined the affinity between urbanization and CO_2 emission. Poumanyvong and Kaneko (2010) proposed theories about the relationship between urbanization and CO_2 emission: The EMT discusses the relationship between urbanization and CO_2 at the national levels, speculating on a rise in environmental pollution due to society's movement from the low to middle stage of progress. It is assumed that people mainly ignore environmental conditions at the early stages instead they endeavor for higher income. However, when these societies reach a certain income level, they focus on improving environmental quality. In contrast, the compact city theory prioritizes the designed urban areas to attain sustainability in urban development. The compact city pattern can help reduce urban struggle and inadequate land use. Compact cities facilitate public transport, local services, and jobs in the densely populated areas. Easy access to public transport reduces contingency on personal vehicle and traffic jams, eventually reducing CO_2 (Miao, 2017).

2.2. Empirical Review

From 1985 to 2021, For Pakistan, Pan et al. (2023) explored the tie between urbanization, trade, energy, technology, and CO_2. They adopted the ARDL model to evaluate the long-term relationship between variables. Surprisingly, GDP and trade declined CO_2, while technology, urbanization, and energy accelerated CO_2. From 1971 to 2017, Danish and Hassan (2023) asserted the interconnection between GDP, urbanization, and CO_2 for Pakistan. GDP and natural resources destroy the environment, while urbanization purifies the environmental quality. For China, Cheng and Hu (2023) explored the connection between urb, technology, and CO_2 emission, employing the STIRPAT model from 1997 to 2018. The outcomes disclosed that urbanization and urban sprawl boost environmental pollution. The attachment between population growth in urban areas, food production, energy use, and CO_2 employing the ARDL model was scrutinized by Rehman et al. (2022) for Pakistan. They found that urbanization reduces CO_2, and GDP and energy use boost CO_2. For the SAARC region, employing the CS-ARDL model, Azam et al. (2022) documented the bond between globalization, industrial growth, innovation, and CO_2. The verifiable outcomes of this research announced that innovation and globalization decrease CO_2 levels, while GDP, urbanization, and energy destroy the environmental quality. Sufyanullah et al. (2022), asserted the bond between urbanization, energy consumption, GDP, and CO_2 emission covering the years 1975 to 2018. All variables lessen CO_2. Anwar et al. (2022) identified the bond between urbanization, energy consumption, FD, and CO_2 for 15 selected Asian countries employing the FMOLS approach. The verifiable outcomes revealed that FD, economic growth, urbanization, and agriculture damage the environment.

Employing the CS-ARDL from 2001 to 2020, Sadiq et al. (2024) focused on the tie between GF, eco-innovation, industrialization, and CO_2 for BRICS countries. They found that all studied variables lessen the CO_2. From 1990 to 2020, Wang et al. (2023) inspected the tie between import, export, GF, and consumption-based CO_2, for 21 OECD countries. The verifiable outcomes of the research proposed that export and green finance reduced CO_2; conversely, imports and GDP exacerbated the CO_2. For 38 OECD countries, Jin et al. (2023), from 2013 to 2021, reported the alliance between GF, GDP, and carbon neutrality utilizing the GMM technique. The observed outcomes of the research unveiled that green bonds and green energy help to achieve carbon neutrality; conversely, uncertainty negatively impacted carbon neutrality. The attachment between green technological innovation, GF, INSQ and CO_2 emissions was identified by Sethi, Behera and Sethi (2024) for 25 developing countries. The empirical findings of the

research unfold that green finance and green technological innovation supported the environmental quality. Gan and Voda (2023) scrutinized the union between green finance, urbanization, capital input, fiscal expenditure, human capital, energy structure, and CO_2 emissions for 30 Chinese provinces. The practical findings disseminated that green finance, human capital, and capital input reduced CO_2 in the environment, while fiscal expenditure and urbanization destroyed the environmental quality. For BRICS countries, Ping and Shah (2023) established the connection between education, FDI, green finance, and CO_2. The economy enhanced CO_2 in all BRICS countries, except India, while green finance and education purified the environmental quality in all BRICS countries.

For OECD countries, from 1990 to 2020, Umar and Safi (2023) focused on the correlation between GF, GDP, import, export, and CO_2 emissions. The GDP and imports destroy the environment, while GF, innovation, and export reduce CO_2. Tariq and Hassan (2023) asserted the tie between GF, GDP, and environmental quality for 70 countries employing the GMM approach. The GF and regulation ameliorate the environmental quality, while carbon finance and GDP degrade the environmental quality. The attachment between green finance, GDP, renewable energy, and CO_2 for 76 developing economies was observed by Bakry et al. (2023). The verifiable outcomes of the research exhibited that green finance, GDP square, and renewable energy clean the environmental quality, while GDP accelerated pollution. Du (2023) asserted the tie between GF, GDP, technological progress, and CO_2 intensity for 10 Asian economies adopting the QARDL model. The GF, technological progress, and renewable energy decreased CO_2. Conversely, GDP demolished the environmental quality. Wan et al. (2022), for 100 developed and emerging nations, identified the connection between green finance, GDP, population, URB, and CO_2. The findings revealed that GDP, urbanization, and demolish the environment, while green finance reduces CO_2. For G-7 countries, Sharif et al. (2022) probed the connection between green finance, green innovation, social globalization, GDP, and CO_2. They found that social globalization and GDP damage the environmental quality, while green finance and innovation purify the ecological quality. Meo and Abd Karim (2022) demonstrated the linkage between GF and CO_2 for the top 10 support GF countries, employing the QQR model. The empirical findings of the research exhibited that green finance has inverse reverberation on CO_2. Tran (2022) for Vietnam established the correlation between green finance, economic growth, energy import, and CO_2. GF reduces CO_2.

For BRICS countries, Ping and Shah (2023) scrutinized the bond between FD, FDI, higher education, green finance, and CO_2, employing the PARDL model. They announced that green finance, higher education, and FDI cleaned the environment, in contrast, GDP and FD deteriorate the ecological peace. Gill, Riaz and Ali (2022) scrutinized the bond between FD, GDP, GDP square, energy consumption, and carbon ejection for Pakistan, spanning from 1980 to 2018, employing the NARDL model. They come to conclude that GDP boost CO_2; conversely, FD abate CO_2. Employing the ARDL model for Pakistan, Usman et al. (2023) documented the interconnection between trade, GDP, FD, and CO_2. The empirical analysis proposed that energy, TO, and GDP demolish the, while FD and renewable energy purify the environmental quality. For South Asian economies, Rani et al. (2022) explored the connection between GDP, FD, education, industry, globalization, and CO_2, covering the years 1990 to 2020. They finally concluded that FD minimizes CO_2, while FD square, globalization, and labor force enhance CO_2. From 1985 to 2020, Batool et al. (2022) for East and South Asia probed the correlation between FD, GDP, Trade, ICT, and CO_2 emissions. They found that Trade and GDP^2 decline CO_2, yet FD and ICT were found unfriendly. Petrović and Lobanov (2022), from 1970 to 2014 for 24 selected countries, scrutinized the link between FDI, FD, GDP, trade, URB, and CO_2 emissions. The empirical findings confirmed that GDP and FD were dangerous for humanity. From 1982-2018, Khan, Teng and Khan (2020) for Pakistan probed the interconnection between stock market development, Oil consumption, domestic credit, FD, GDP, and CO_2. The statistical conclusion aggravated that domestic credit negatively correlated with CO_2, GDP, FD, and oil consumption, deteriorated the health of environment.

Farooq, Leong, et al. (2024) identified the connection between corruption, human capital, FDI, and environment covering the years 1996 to 2022, employing the NARDL model for Pakistan. FDI and human capital support environment; conversely, GDP demolishes environmental quality. For Pakistan, the attachment between tourism, green finance, globalization, GDP, and CO_2 covering the years 1989 to 2022 was explored by Farooq, Shah, et al. (2024a). They found that green finance reduced CO_2, while GDP, globalization, and tourism damaged the environment

quality. Employing NARDL for Pakistan, Nousheen, Farooq and Faheem (2024) evaluated the nexus between energy consumption, institutional quality, industry, and the environment. The empirical outcomes of this research aggravated that energy, INSQ, and industry amplified CO_2; conversely, trade controls CO_2 emissions. For Pakistan, employing the ARDL model, from 1987-2022, Farooq, Leong, et al. (2024) documented the bond between FDI, FD, green growth, green growth, and the environment. They revealed that green growth and FD support the eco system, while FDI and GDP diminish the environmental quality. Wei et al. (2024) asserted the association among FD, ICT, NRE, and CO_2 emissions for Pakistan employing the ARDL model. The outcomes of this research uncovered that FD minimized CO_2, while FDI, ICT, and NRE acted adversely. Farooq, Leong, et al. (2024) found the favorable connection between GDP and FDI with CO_2, while fintech negatively associated with CO_2 for Pakistan covering the years 1995 to 2023 adopting the NARDL model. From 2004 to 2021, The financial inclusion, trade, FDI, GDP, and CO_2 for Pakistan was identified by Faheem, Farooq, et al. (2023). The practical findings of this research announced that trade and financial inclusion decrease CO_2, while GDP and FDI boost CO_2. Farooq, Faheem and Nousheen (2023b) for Pakistan covering 1995 to 2021, utilizing the ARDL model, explored the bond between EPU, URB, renewable energy, and CO_2 emissions. They witnessed that economic policy uncertainty, FDI, and URB worked against environment, while renewable energy cleans the environmental quality. For Pakistan, Faheem, Nousheen, et al. (2023) documented the bond between fiscal decentralization, NRE, RNE, and CO_2 by employing the ARDL. They concluded that fiscal decentralization and RNE supported the environmental quality. Farooq, Faheem and Nousheen (2023b) evaluated the interrelatedness between RNE, urbanization, GDP, and CO_2 for Pakistan. The results confirmed that TNRR, and RNE declined CO_2, while GDP and urbanization accelerated CO_2.

3. Data and Methodology

This study scrutinizes the association between GF, urbanization, financial development, GDP, and environmental sustainability, using yearly figures from 1983 to 2023. All data was taken from WDI. The CO_2 emissions are measured in (total) excluding LULUCF (Mt CO_2), urbanization (Urban population), Financial development (Broad money (% of GDP)), green finance (% of total final energy consumption)), and GDP (GDP growth (annual %)). The mathematical equation is given below.

$$CO2 = f(URB, FD, GF, GDP) \quad (1)$$

$$CO_{2_t} = \vartheta_1 + \vartheta_2 URB_t + \vartheta_3 FD_t + \vartheta_4 GF_t + \vartheta_5 GDP_t + \mu_t \quad (2)$$

Where CO_2 represent CO_2 emissions, URB represent urbanization, GF represent Green finance, FD represent financial development, GDP represents economic growth in given time period t, ϑ represents coefficients of variables and μt represents error term. Non-linear Auto-Regressive Distributive Lag model proposed by Shin, Yu and Greenwood-Nimmo (2014) was applied to diagnose the asymmetric influence of green finance, financial development, urbanization, and GDP on environment. The NARDL technique is superior to the traditional ARDL technique on some basis. Firstly, it is helpful to scan the asymmetric relationship between sampled factors. Secondly, NARDL examines the short and long-run asymmetric relationship between response and manipulated variables, which helps to evaluate the changes in independent variables over time. Thirdly, as NARDL captures dual effects, it is beneficial in formulating the policies. Fourthly, NARDL encapsulates symmetric and asymmetric long-run relationships. The long-run equation for NARDL is as follows.

$$\Delta CO_{2_t} = \vartheta_1 + \sum_{v=1}^{O1} \vartheta_{2i} \Delta\, CO_{2_{t-i}} + \sum_{v=0}^{O2} \vartheta_{3i} \Delta\, URB^{+}{}_{t-i} + \sum_{v=0}^{O3} \vartheta_{4i} \Delta\, URB^{-}{}_{t-i} + \sum_{v=0}^{O4} \vartheta_{5i} \Delta\, FD_{t-i} + \sum_{v=0}^{O5} \vartheta_{6i} \Delta\, GF_{t-i} + \sum_{v=0}^{O6} \vartheta_{7i} \Delta\, GDP_{t-i} + \epsilon_1 CO_{2_{t-1}} + \epsilon_2 URB^{-}{}_{t-1} + \epsilon_2 URB^{+}{}_{t-1} + \epsilon_3 FD_{t-1} + \epsilon_4 GF_{t-1} + \epsilon_5 GDP_{t-1} + \mu_t \quad (3)$$

$$\Delta CO_{2_t} = \vartheta_1 + \sum_{i=1}^{p1} \vartheta_{2i} \Delta\, CO_{2_{t-i}} + \sum_{i=0}^{p2} \vartheta_{3i} \Delta\, URB_{t-i} + \sum_{i=0}^{p3} \vartheta_{4i} \Delta\, FD_{t-i} + \sum_{i=0}^{p4} \vartheta_{5i} \Delta\, GF_{t-i} + \sum_{i=0}^{p5} \vartheta_{6i} \Delta\, GDP_{t-i} + \lambda ECT - 1 + vt_t \quad (4)$$

Various diagnostic tests, including the normality test, autocorrelation, heteroscedasticity, and Ramsey RESET test, were applied to evaluate the model's dependability. In addition, CUSUM and CUSUMQ stability assessments were also performed.

3.1. Empirical Findings and Discussions

Before beginning any regression review, examining the fundamental aspects of variables and their relationships is imperative. Based on the findings of descriptive statistics described in Table 1, urbanization has the highest average value (17.70264), while GDP has the lowest average value (1.43124). The standard deviations for all variables witnessed stability as the values were lower than their average. Jarque-Bera's results indicate a normal distribution.

Table 1: Summary Statistics

	CO_2	UR	FD	GF	GDP
Mean	4.602829	17.70264	3.747708	3.876109	1.431244
Median	4.706878	17.7318	3.799682	3.863869	1.493285
Maximum	5.282027	18.1946	3.927981	4.062166	2.058123
Minimum	3.634344	17.09702	3.356531	3.698582	0.014293
Std. Dev.	0.469823	0.336813	0.137279	0.095696	0.491845
Skewness	-0.54197	-0.20957	-1.30168	0.04432	-0.97712
Kurtosis	2.19714	1.826972	4.152493	2.280998	3.672798
Jarque-Bera	2.577666	2.198199	11.48308	0.743497	6.051606
Probability	0.275592	0.333171	0.00321	0.689528	0.048519
Sum	156.4962	601.8896	127.4221	131.7877	48.66229
Sum Sq. Dev.	7.284198	3.743612	0.621904	0.302202	7.98308
	CO_2	UR	FD	GF	GDP
CO_2	1				
UR	0.987512	1			
FD	0.214747	0.219129	1		
GF	-0.94143	-0.95492	-0.16092	1	
GDP	-0.33032	-0.31324	-0.20675	0.344563	1

Table 2 represents the empirical findings of ADF and PP. The findings of both ADF and PP revealed that urbanization and green finance were stable at the first level, and the remainder of the studied variables were stable at the first difference.

Table 2: Stationarity Tests

Variable	ADF		PP	
	Level	First Difference	Level	First Difference
CO_2	-0.209	-3.014***	-0.023	-2.506***
URB	-4.210***	-4.329***	-4.503***	-5.404***
FD	-3.486	-2.398***	-1.034	-2.523***
GF	-4.170**	-1.503***	-2.321**	-4.232***
GDP	-0.321	-5.492***	-0.325	-3.263***

Bound test results revealed the co-integration evidence among variables. The results in table 3, F-statistics is 7.021 which is clearly higher than upper bound that reveal the confirmation of cointegration.

Table 3: Bound Test

F-statistic	Range	Critical values	
		I(0) bound	I(1) bound
7.021	10%	2.26	3.35
	5%	2.62	3.79
	1%	3.41	4.68

The statistical findings of NARDL are shared in Table 4. This analysis evaluates the non-linear union between urbanization, green finance, GDP, FD, and CO_2 via the NARDL technique. The long-run results indicate the dual coefficients of variables. The NARDL findings revealed that slop parameters of URB with dual shocks are 1.074 and -0.535 individually. The results indicate that urbanization positively influences CO_2 emissions and degrades environmental health in positive shocks. The analysis imply that a 1 unit rise in urbanization will increase 1.074% degradation. This positive relationship shows the destructive role of urbanization on ecological health. Pan et al. (2023) For Pakistan, Cheng and Hu (2023) for China observed the same calculations. On the other hand, urbanization acts differently in negative shocks. In negative shocks, urbanization negatively influences CO_2. The findings indicate that a 1 unit rise in urbanization will reduce 0.535% of degradation. The adverse affinity between urbanization and CO_2 confirms the constructive role of urbanization in negative shocks. The same results were found by Danish and Hassan (2023) for Pakistan. In terms of financial development, the findings

unfold a negative association between FD and CO_2, implying that one-unit surge in FD will lessen 0.095% CO_2. The relationship was found to be significant at a 5% level. Our findings are parallel to Usman et al. (2023) for Pakistan, Rani et al. (2022) South Asian economies. Based on the findings of green finance, specifically the negative correspondence with ecological degradation, green finance was found to be significant at a 5% level. The conclusion imply that 1unit expansion in GF will be responsible for a 0.746% drop in CO_2. The negative affinity between GF and CO_2 mentions the supportive role of GF on environment quality. The same results were found by Sadiq et al. (2024) for BRICS countries and Wang et al. (2023) for OECD countries. Finally, the findings unveil a detrimental relationship between GDP and CO_2, indicating a 1 unit surge in GDP will deteriorate the environment by 0.572%. In the long run, the relationship damages environment quality. This positive relationship confirms the destructive role of GDP on CO_2. our findings are alike (Farooq, Shah, et al., 2024a) and Faheem et al. (2024) for Pakistan.

Table 4: Long and Short Run Estimates

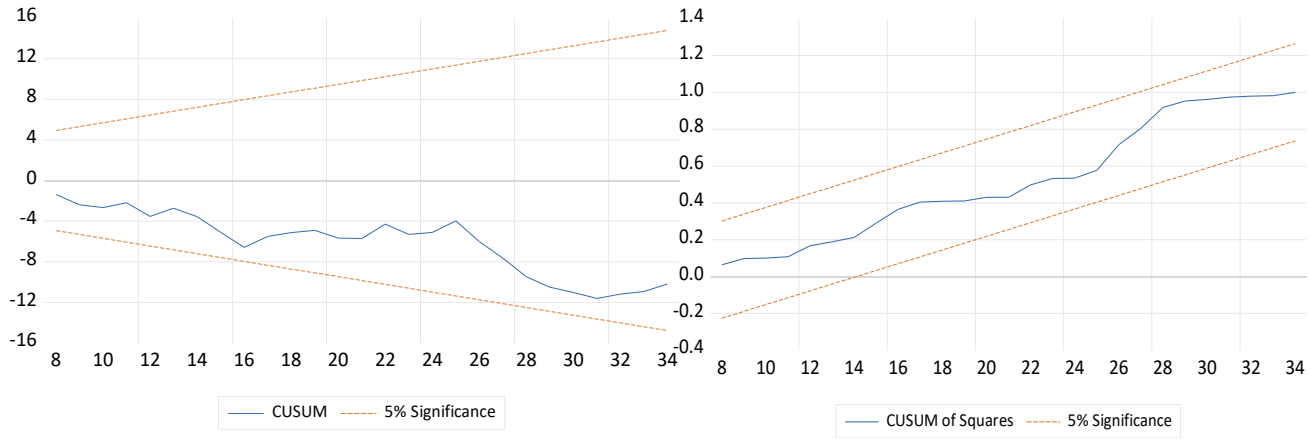
Variables	Coefficient	[S.E]	{T-st}.
Long Run			
URB^{pos}	1.074***	[0.100]	{10.675}
URB^{neg}	-0.535**	[0.141]	{-3.784}
FD	-0.095**	[0.043]	{-2.176}
GF	-0.746**	[0.255]	{-2.912}
GDP	0.572**	[0.178]	{3.200}
Short Run			
$D(URB)^{pos}$	0.311**	[0.116]	{2.665}
$D(URB)^{NEG}$	0.710***	[0.080]	{8.772}
D(FD)	0.229**	[0.078]	{2.944}
D(GF)	0.052***	[0.017]	{2.954}
D(GDP)	0.461***	[0.108]	{4..244}
CointEq(-1)	0.170**	[0.021]	{7.843}

The diagnostic tests indicate that the model is well-fitted, with a high R^2 (0.987) and Adj. R^2 (0.982), and no issues of autocorrelation (D-W = 2.345), heteroskedasticity (p = 0.710), misspecification (Ramsey RESET, p = 0.148), or non-normality of residuals (Jarque-Bera, p = 0.438). Additionally, the LM test confirms no serial correlation (p = 0.134).

Table 5: Diagnostic Tests

R^2	0.987
Adj R^2	0.982
D-W	2.345
LM	0.762(0.134)
Jarque-Bera	0.880(0.438)
Hetero	0.622(0.710)
Ramsey	1.530(0.148)
CUSUM	Stable
CUSUMQ	Stable

Figure 1: CUSUM, CUSUMQ



4. Conclusion and Policy Suggestions

The reverberations of urbanization, GF, FD, and GDP on CO_2 in Pakistan is assessed between 1983 and 2023. The NARDL findings unfolded positive ramification of URB on CO_2 in positive shocks, urbanization enhances CO_2 and degrades the environment, but in negative shocks, urbanization mitigates CO_2 and purifies the ecosystem. The findings show that higher levels of GF and FD minimize CO_2 in Pakistan in the long run, while GDP follow EKC hypothesis. GDP affects the environment adversely. From empirical outcomes and the literature reviewed, current study proposed following strategic initiatives. First, the government of Pakistan should focus on planned urbanization, which can reduce CO_2 feasibly. Secondly, Pakistan must enforce policies to build low-carbon cities and circular economies. Additionally, the government should concentrate on recycling of waste and pollutants. Thirdly, the Pakistani government should arrange land and population according to local needs to create compact and efficient cities. At the same time, to protect environmental quality, Green areas should be set aside in the cities, which will help reduce CO_2 mission and pollution. Fifthly, using green materials instead of steel and cement in construction sectors could help reduce pollution and promote eco-friendly construction. Moreover, empirical findings indicate a strong influence of FD on Pakistan's environmental quality. That's why the government of Pakistan should acknowledge financial reforms for policy formulation. The law makers should be enforced to implement laws and regulations for green investment practices by encouraging an energy-efficient strategy. The government should encourage clean and green energy projects with energy-efficient equipment in the industrial and agriculture sectors. As far as the use of green bonds has achieved the carbon neutrality objective, it is recommended that Pakistan should promote the incentive for green finance and enforce transparent allocation of funds for green technologies to decrease the uncertainties in green projects. The government should formulate policies to curtail the import of energy-intensive goods and services; instead, energy-efficient technologies should be promoted.

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