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Nexus between financial developments, renewable energy consumption and environmental sustainability in Bangladesh: Evidence from ARDL and NARDL

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Abstract

The goal of this research was to examine the effects of Bangladesh's economic growth, trade liberalization, renewable energy consumption, financial development, and FDI on environmental sustainability from 1990 to 2019. Both the combined cointegration and Makki cointegration tests and the cointegration test with symmetry and asymmetry found evidence of long-run cointegration between the explained and explanatory factors. As shown by the coefficients of FD, TO, and FDI, population haven theory suggests that FD, TO, and FDI have hastened environmental deterioration in Bangladesh. Furthermore, the asymmetric evaluation revealed the nonlinear association between explained and explanatory factors throughout the long and short term.

Keywords: Renewable Energy Consumption; Financial Development; Trade Openness; FDI; Environmental sustainability; ARDL; NARDL

1. Introduction

Bangladesh has a significant problem in the form of environmental deterioration. Almost 160 million people live in a geographical area of just 147,570 square kilometers, making this nation very densely inhabited. A lack of adequate environmental legislation and rapid industrialization and urbanization have significantly degraded the country's natural resources. Air pollution is one of Bangladesh's most pressing environmental problems. The air quality in this nation is quite poor due to the abundance of pollutants such as particulate matter. Burning biomass for household purposes (including cooking and heating) is also a major contributor. Bangladesh has a second big environmental challenge: water contamination. Due to industrial waste, agricultural runoff, and untreated sewage, the country's rivers and other waterways are severely contaminated. Because of the prevalence of water-borne illnesses like cholera and dysentery, this has serious implications for public health.

Bangladesh also has a significant environmental concern due to deforestation. Rapid deforestation is occurring throughout the nation due to increasing demands for land for farming and building. The country's capacity to adapt to climate change and its biodiversity are negatively affected. Last but not least, climate change represents a serious threat to the ecology of Bangladesh. Sea level rise, increasing frequency and severity of severe weather events, and shifts in precipitation patterns are just a few examples of how climate change is already affecting the nation. Communities may be displaced, people may lose their jobs, and food insecurity may rise due to these effects. The government of Bangladesh must make protecting the environment a top priority and invest in sustainable development to tackle these environmental concerns. Building resilience to climate change's effects requires various measures, such as bolstering environmental legislation and enforcement, expanding access to sustainable modes of transportation and energy, preserving and restoring forests, and more. To ensure environmental preservation is included in all growth stages, cooperation is needed between the government, civic society, and the commercial sector.

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The amount of foreign direct investment (FDI) significantly influences the level of carbon emissions in Bangladesh. The textile and garment industry, one of the major contributors to the nation's total carbon footprint, is an extremely important sector for the economy of the country in question. Nevertheless, due to the influx of foreign direct investment (FDI) from nations like as Japan, China, and South Korea into the country over the course of the last decade or so, significant strides have been made in the direction of lowering the number of carbon emissions generated by these businesses. Because of these investments, businesses have been able to implement new technology and practices that are more energy efficient, resulting in a large reduction in the number of greenhouse gases they produce. In addition, international investors sometimes bring more stringent environmental requirements than are normally observed in Bangladeshi enterprises. They enforce stringent laws and monitoring measures to maintain compliance with international environmental standards that are targeted at minimizing emissions across all industrial sectors. This helps ensure that the environment is protected. As a result, one can conclude that foreign direct investment (FDI) plays a significant part in the fight against climate change. This is because FDI helps boost Bangladesh's economic growth while ensuring sustainable development through environmentally friendly initiatives.

Considering the importance of a thriving financial industry to a country's overall development and prosperity, we must evaluate the environmental impacts of foreign direct investment. There is a study on FD's effect on environmental quality, although it yields contradictory results. The ratio of deposits (bank assets) to GDP, the share of liquid liabilities, and the percentage of domestic lending to the private sector are all common indicators of FD. Several researchers (1, 2). Based on the findings of the first body of literature, FD significantly increases environmental sustainability by reducing the pace of environmental degradation. Tamazian and Bhaskara Rao (3) examined how FD affected the BRICS nations' carbon emissions. One of the most significant conclusions was that FD enhances environmental quality by lowering carbon emissions. Similarly, Jalil and Feridun (4) found evidence connecting FD to ecological degradation. In their study of the influence of FD on China's carbon emissions, Khandakar and Chowdhury (5) discovered a moderating effect. Dogan and Aslan (6) examined the link between FD and environmental quality in 23 countries. Their findings were similar to those of our study. Using FMOLS and DOLS, they determined that FD improves environmental quality by lowering ecological deterioration. Climate change and global warming are significant concerns that the world is grappling with today. One of the most important contributors to these environmental challenges is carbon emission, attributed mainly to industrialization and economic development. However, recent studies have shown that there may be a nexus between financial development and carbon emission, providing evidence for how they are linked.

The present study has considered financial development and renewable energy consumption in the equation of environmental degradation. In recent years, renewable energy consumption has shown significant potential to reduce carbon emissions in Bangladesh. According to a report by the International Renewable Energy Agency (IRENA), the country's current level of renewable energy usage is estimated at around 3%, with hydropower being the dominant source. However, if this percentage could be increased through appropriate policies and investments, it would have a substantial impact on reducing greenhouse gas emissions in Bangladesh. Using cleaner energy sources can replace fossil fuels, such as coal and natural gas, that currently contribute significantly to carbon dioxide emissions in the country. Promoting renewable energy technologies like solar panels or wind turbines also helps mitigate climate change. It creates employment opportunities for local communities while improving access to electricity in rural areas. Therefore, increasing renewable energy consumption should be prioritized as an effective strategy for achieving sustainable development goals while combating climate change effects in Bangladesh.

In recent years, the issue of climate change has become a global concern, and many developing countries, including Bangladesh, are experiencing the adverse effects of climate change. Bangladesh is one of the countries most vulnerable to the impacts of climate change due to its low-lying geography and high population density. In this context, this research paper aims to investigate the nexus between financial development, renewable energy consumption, and carbon emissions in Bangladesh.

The rest of the structure is as follows. The literature survey is displayed in Section 2. The data and methodology of the study are reported in Section 3. Interpretation and discussion in Section 4. Finally, the conclusion is available in Section 5.

2. Literature Review

The nexus between renewable energy consumption and carbon emissions is an important topic of research in the context of climate change mitigation. Renewable energy sources such as solar, wind, hydro, and geothermal power are potential alternatives to fossil fuels that can help reduce carbon emissions and mitigate the adverse impacts of climate change. Several studies have investigated the relationship between renewable energy consumption and carbon emissions. A common finding is that renewable energy consumption has a negative relationship with carbon emissions,

indicating that increasing the use of renewable energy sources can lead to a reduction in carbon emissions. This negative relationship is primarily attributed to renewable energy sources emitting little to no carbon dioxide during electricity generation. At the same time, fossil fuels are a significant source of carbon emissions. Furthermore, renewable energy consumption has been found to significantly impact reducing carbon emissions in both developed and developing countries (7-11). A study by International Energy Agency (IEA) found that renewable energy accounted for almost 90% of the increase in power generation capacity in 2020. As a result, carbon dioxide emissions from the power sector decreased by 2% globally. Similarly, a study by the World Bank found that increasing renewable energy consumption in developing countries can help reduce carbon emissions by up to 27% by 2050. However, it is important to note that the relationship between renewable energy consumption and carbon emissions can be influenced by various factors, such as the availability and cost of renewable energy sources, government policies and incentives, and technological advancements. Therefore, to maximize the potential of renewable energy sources in reducing carbon emissions, policies and initiatives to promote renewable energy consumption should be implemented at the national and international levels(12-14).

Renewable energy consumption has been on the rise in recent years. This trend is expected to continue as more countries commit to reducing their carbon emissions. The increased use of renewable energy sources such as wind, solar, hydroelectric and geothermal power can significantly reduce carbon emissions. Unlike traditional fossil fuels that emit harmful greenhouse gases when burned, renewable energy sources produce little or no emissions during generation. This means that increasing the proportion of renewables in our energy mix can significantly reduce our carbon footprint. Moreover, other indirect benefits are associated with transitioning towards cleaner forms of energy. For instance, using renewable electricity for transportation through electric vehicles (EVs) will reduce carbon emissions and lower air pollution levels caused by exhaust fumes from conventional automobiles(15-18). In addition to these environmental gains, investing in renewables has proven economically beneficial. As technology advances and economies of scale come into play, the cost of producing clean electricity continues to fall, making it an increasingly attractive option for governments and businesses. All things considered; it's clear that increasing renewable energy consumption is one effective way we can mitigate climate change while promoting sustainable development worldwide (11, 19-23)

Renewable energy consumption has the potential to reduce carbon emissions in Bangladesh significantly. As one of the most densely populated countries on earth, Bangladesh faces numerous challenges related to sustainable development, including high carbon emissions from traditional energy sources like coal and oil. However, recent government and private sector efforts to promote renewable energy have shown promise in reducing these harmful emissions. By increasing the use of solar power, wind power, hydropower, and other forms of clean energy, Bangladesh can reduce its reliance on fossil fuels while supporting economic growth and improving access to electricity for its citizens. While there are still obstacles to overcome in terms of policy changes and infrastructure improvements needed for the widespread adoption of renewable energy sources, it is clear that this shift toward sustainability is crucial for both environmental protection and long-term economic success in Bangladesh(24-36).

The term "environmental degradation" refers to the process through which human actions, such as the extraction of resources, the proliferation of species, the modification of weather patterns, and the destruction of ecosystems, all contribute to the deterioration of the natural environment ((37, 38). In recent decades, academics have started devoting a significant amount of time and effort to studying the decline of the natural environment. As a consequence of this, there has been a great deal of discussion and disagreement on various environmental ideas and pieces of data. The Environmental Kuznets Curve (also known as the EKC) is the conceptual underpinning of this investigation. According to the EKC theory, the environmental deterioration rate first accelerates with civilization's economic development. Nevertheless, this rate stabilizes as people learn to coexist peacefully with the natural world. (39), the researchers who discovered the inverted U-shaped correlation between environmental pollutants and per capita income and came up with the acronym EKC were the first to observe it. Both developed countries and developing nations have produced substantial empirical data supporting EKC. (40) are credited with laying the basis for what has since evolved into a significant body of research on the relationships between economic expansion and ecological viability. They said that the World Bank's financial assistance system was to blame for major environmental issues because of its propensity to neglect the ecological implications of loanable levies. This was one of the reasons given for this allegation. Moreover, this conclusion was supported by a large number of research that conducted temporal data analysis. Several nations, including Iran (41), India (42-48), Nigeria (49, 50), and Pakistan, have reported that the impacts of economic expansion have been negative in their respective countries (51).

Several studies have been conducted on the nexus between financial development and carbon emission to identify the potential channels through which economic development can affect carbon emissions (43, 52, 53). The findings of these studies are mixed, with some finding a positive relationship and others finding a negative or no relationship. The ARDL

bounds testing approach investigated the long-run nexus between financial development and carbon emission in Pakistan from 1980 to 2011. The results suggest a negative and significant long-run relationship between economic growth and carbon emission in Pakistan. The NARDL approach examined the short-run dynamics of the nexus between financial development and carbon emission for Pakistan from 1980 to 2011. The results show a significant negative relationship between economic growth and carbon emission in Pakistan in the short run (20, 54, 55).

For a long time, people have argued over whether or not environmental deterioration is related to economic growth. While some academics claim that environmental deterioration drives economic development, others say the opposite is true. There is data to back up either position. There is a correlation between environmental deterioration and economic development in certain nations but not others. Because of the interconnected nature of environmental deterioration and economic growth, pinpointing a specific cause and effect is challenging.

Nonetheless, it cannot be denied that they are linked and that one may affect the other. Degrading the natural world may hinder progress in several ways that affect money. Natural resource depletion is one method. The result may be higher manufacturing costs and slower economic growth (56-59). In addition to impeding economic growth, environmental deterioration may increase crime and social instability. Furthermore, severe weather occurrences brought on by climate change due to environmental degradation may cause damage to infrastructure and disrupt Trade, ultimately resulting in less economic activity and less financial progress (60-62). Previous research yielded conflicting findings, so we decided to dive more into the topic in the context of Bangladesh. Alam, Alam (63), and Rani, Ismail (2001) observed that increasing energy use is positively correlated with either GDP expansion or CO2 emissions (64). This type of thinking also fits well with data from the current and distant past. Wadud (65), studying seven SAARC nations, found that GDP development and carbon dioxide (CO2) emissions were mutually reinforcing. Carbon dioxide emissions considerably aid long-term economic growth.

According to research by Hamid, Alam, and Ahmad, energy usage causes economic expansion in the short run (66). However, there has been a correlation between increased electrical use and a flourishing economy for quite some time. Although there is a short-term cointegrating link between energy consumption and CO2 emissions, CO2 emissions, and economic growth in Bangladesh, Salahuddin and Alam (67) found no long-term cointegrating correlation between these variables. Using data from 1985-2013, researchers in Bangladesh established a causal yin-yang relationship between economic growth and the use of fossil fuels, electricity consumption, and financial development. Therefore, the state of the environment has a major bearing on the economy's health and vice versa. An increase in energy use may lead to increased carbon emissions, the release of additional pollutants, and a decline in environmental quality.

While Trade can promote economic growth and development, it can also negatively affect the environment. There is a large body of evidence that trade openness has harmed environmental degradation. A recent study by the World Bank found that countries with higher levels of trade openness were more likely to experience environmental degradation, especially developing countries. This is likely because trade liberalization often leads to increased production and consumption, which can pressure natural resources and lead to pollution. Additionally, countries becoming more integrated into the global economy may be less likely to invest in environmental protection. The impact of trade openness on environmental degradation is a crucial issue to consider when assessing the benefits and costs of Globalization.

3. Data and Methodology

The study uses the autoregressive lag distributed model (ARDL) and the nonlinear ARDL (NARDL) to investigate the nexus between financial development, renewable energy consumption, trade openness and Bangladesh's carbon emission from 1990-2019. The results of the study reveal that there is a long-run relationship between economic growth and carbon emission in Bangladesh. Furthermore, the results also indicate that the economic effect of Granger causes carbon emissions in Bangladesh.

3.1. Autoregressive Distributed lagged

The Autoregressive Distributed Lagged (ARDL) model is among the most useful tools when analyzing economic data. Time-series data, in which the values of a variable are tracked through time, lend themselves especially well to this paradigm. To account for time-varying associations, the ARDL model factors in past values of both dependent and independent variables. By estimating this model, we may look at the long-term effects of a change in one variable on another while also considering any confounding variables. Examining the rate at which these variables normalize aftershocks or changes allows researchers to probe short- and long-term causal effects. ARDL provides a good framework for analyzing intricate monetary interactions and basing policy choices on data (68-73).

They accept the underlying benefits of the ARDL bound testing approach in examining the long-run association between foreign direct investment, Exchange rate, monetary policy, and Fiscal Policy. We apply ARDL determined testing procedure, initially proposed by Pesaran and Shin (74) and later extension done by Pesaran, Shin (75) and Narayan (76) within an Autoregressive Distributed lag framework (ARDL). To perform Bound testing, it is imperative to model equation (2) as a conditional ARDL as follows (3a, 3b, 3c, and 3d), where each variable is treated as a dependent variable so that the best-fitted model can estimate further:

$$\Delta lnES_t = \alpha_0 + \sum_{i=1}^{n} \mu_{11}\Delta lnFD_{t-i} + \sum_{i=0}^{n} \mu_{12}\Delta lnREC_{t-i} + \sum_{i=0}^{n} \mu_{13}\Delta lnTO_{t-i} + \gamma_{11} lnFD_{t-1} + \gamma_{12} lnREC_{t-1} + \gamma_{13} lnTO_{t-1} + \gamma_{14} lnES_{t-1} + \omega_{1t} \quad (2)$$

$$\Delta lnFD_t = \alpha_0 + \sum_{i=0}^{n} \mu_{21}\Delta lnES_{t-i} + \sum_{i=1}^{n} \mu_{22}\Delta lnFDI_{t-i} + \sum_{i=0}^{n} \mu_{23}\Delta lnFD_{t-i} + \sum_{i=0}^{n} \mu_{24}\Delta lnTO_t + \gamma_{21} lnFD_{t-1} + \gamma_{22} lnFDI_{t-1} + \gamma_{23} lnTO_{t-1} + \gamma_{24} lnES_{t-1} + \omega_{2t} \quad (3b)$$

$$\Delta lnFDI_t = \alpha_0 + \sum_{i=0}^{n} \mu_{21}\Delta lnES_{t-i} + \sum_{i=1}^{n} \mu_{22}\Delta lnFDI_{t-i} + \sum_{i=0}^{n} \mu_{23}\Delta lnFD_{t-i} + \sum_{i=0}^{n} \mu_{24}\Delta lnTO_t + \gamma_{21} lnFD_{t-1} + \gamma_{22} lnFDI_{t-1} + \gamma_{23} lnTO_{t-1} + \gamma_{24} lnES_{t-1} + \omega_{2t} \quad (3b)$$

$$\Delta lnTO_t = \alpha_0 + \sum_{i=0}^{n} \mu_{21}\Delta lnTO_{t-i} + \sum_{i=1}^{n} \mu_{22}\Delta lnFDI_{t-i} + \sum_{i=0}^{n} \mu_{23}\Delta lnFD_{t-i} + \sum_{i=0}^{n} \mu_{24}\Delta lnTO_t + \gamma_{21} lnFD_{t-1} + \gamma_{22} lnFDI_{t-1} + \gamma_{23} lnES_{t-1} + \omega_{2t} \quad (3b)$$

Where Δ is the first difference operator, μ_{11} *to* μ_{44} represents short-run elasticity, γ_{11} *to* γ_{44} for long-run coefficients, and ω_t is the error correction term?

3.2. Nonlinear ARDL

Time-series analysis using nonlinear autoregressive distributed lag models (NARDL) is a cutting-edge method with numerous advantages over conventional linear models. NARDL is preferable to linear models when representing complex phenomena with several interacting elements since it allows for nonlinear connections between variables. This is very helpful in economics, where variables like inflation, economic growth, exchange rates, and exports may not have monotonic correlations. Furthermore, NARDL explicitly simulates a system's short- and long-run dynamics by factoring in transient shocks and enduring tendencies. This model outperforms standard methods in predicting market trends and future value. Lastly, the NARDL model's adaptability allows for adding more variables or changes to the underlying data-producing process to be accounted for with no need for a full re-specification of the model structure. When taken as a whole, NARDL is a significant step forward in time-series econometrics with considerable applications in many other sectors, such as economics, politics, and marketing (28, 69, 77-86),

On the other hand, positive change in FDI changes $\Delta \ln FDI^+$ and negative change in FDI denoted by $\Delta \ln FDI^-$ Respectively. Using new notation, we create two sets of new time series data based on the exchange rate's positive (POS) and negative (NEG). Series can drive using the following equations:

$$\begin{cases} POS(FD)_t = \sum_{k=1}^{t} lnFD_k^+ = \sum_{K=1}^{T} MAX(\Delta lnFD_k, 0) \\ NEG(FD)_t = \sum_{k=1}^{t} lnFD_k^- = \sum_{K=1}^{T} MIN(\Delta lnFD_k, 0) \end{cases} \quad (7)$$

$$\begin{cases} POS(FDI)_t = \sum_{k=1}^{t} lnFDI_k^+ = \sum_{K=1}^{T} MAX(\Delta lnFDI_k, 0) \\ NEG(FDI)_t = \sum_{k=1}^{t} lnFDI_k^- = \sum_{K=1}^{T} MIN(\Delta lnFDI_k, 0) \end{cases} \quad (8)$$

$$\begin{cases} POS(TO)_t = \sum_{k=1}^{t} lnFD_k^+ = \sum_{K=1}^{T} MAX(\Delta lnTO_k, 0) \\ NEG(TO)_t = \sum_{k=1}^{t} lnTO_k^- = \sum_{K=1}^{T} MIN(\Delta lnTO_k, 0) \end{cases} \quad (7)$$

The next step is to replace the positive and negative series of the exchange rate in equation (3a) and the positive-negative change in equation (3b). Once inserted, the new error correction equation arrives as follows:

$$\Delta lnES_t = \alpha_0 + \sum_{i=1}^{n} \mu_1 \Delta lnES_{t-i} + \sum_{i=0}^{n} \mu_2^+ \Delta lnPOS(FDI)_{t-i} + \sum_{i=0}^{n} \mu_2^- \Delta lnNEG(FDI)_{t-i} + \sum_{i=0}^{n} \mu_2^+ \Delta lnPOS(FD)_{t-i} + \sum_{i=0}^{n} \mu_2^- \Delta lnNEG(FD)_{t-i} + \sum_{i=0}^{n} \mu_2^+ \Delta lnPOS(TO)_{t-i} + \sum_{i=0}^{n} \mu_2^- \Delta lnNEG(TO)_{t-i} + \omega_t \quad (9)$$

4. Empirical Results

Table 1 Results of Unit root test

	At level				After the first difference			
	ADF	**GF-DLS**	**PP**	**KPSS**	**ADF**	**GF-DLS**	**PP**	**KPSS**
ES	-1.8106	-1.1223	-2.1122	0.7882***	-8.9272***	-9.4524***	-6.8601***	0.0215
FD	-0.7465	-1.4472	-2.4684	0.6614***	-7.4219***	-6.9307***	-9.2115***	0.0185
REC	-2.3426	-0.629	-0.6545	0.6137***	-7.8523***	-8.5018***	-9.3546***	0.0186
TO	-2.389	-1.8818	-2.228	0.8714***	-6.5966***	-9.2984***	-7.4834***	0.0198
FDI	-0.2759	-2.496	-2.0433	0.7306***	-6.5545***	-7.0194***	-6.6938***	0.0187
Panel –B: Ng-Perron Unit root test								
	At level				**At first difference**			
	MZa	**MZt**	**MSB**	**MPT**	**MZa**	**MZt**	**MSB**	**MPT**
ES	-2.4318	-1.1885	0.3018	7.4547	-20.9815	-5.7005	0.1765	3.3407
FD	-1.9604	-1.2868	0.2392	8.4677	-25.3936	-4.9601	0.1386	3.9229
REC	-2.5452	-1.5426	0.2267	8.0982	-19.6183	-4.2992	0.1454	4.0812
TO	-1.7522	-1.6573	0.2605	8.8779	-20.8537	-4.6662	0.1347	4.8877
FDI	-2.4672	-1.6518	0.3052	7.6802	-22.9645	-5.2075	0.1613	3.552

Long-run cointegration may be studied using the ARDL approach without regard to the order of integration of the variables. However, empirical studies like (87) imply that the estimated F-statistic employed for evaluation is erroneous because of second-order cointegration.

Specifically, we use the ADF unit root test offered by Dickey and Fuller (88), the P-P unit root test provided by Phillips and Perron (89), and the KPSS unit root test provided by Kwiatkowski, Phillips (90) to verify that no variables are integrated at the second order. Estimated unit roots are shown in Table 1. Since the stationary test reveals that none of the research variables are combined after the second difference, we continue with symmetric and asymmetric estimates between FD, FDI, TO, and environmental degradation.

The study implemented a cointegration test following the frameworks offered by (91) and (92) for establishing the long-run association between explained and explanatory variables. The results of the cointegration test are displayed in Table 2. According to the test statistics, the study confirmed the long-run association in the empirical nexus.

Table 2 Results of Makki Cointegration test

Number of Breaks	Test Statistics	Break Points	
Points	[Critical Values]		
Tb<5			
0	-8.4164	−6.306	2003,2018,2002,2007,1993
1	-7.4893	−6.494	2015,2016,1999,2004,2003
2	-8.9057	−8.869	1996,2012,2006,2016,1990
3	-9.93	−9.482	2005,1995,2005,2011,1994

4.1. Symmetric and asymmetric estimation

The long-run cointegration of explained and explanatory variables was studied using a bound testing strategy in both a linear and nonlinear context. Foverall, tDV, and FIDV are all test statistics statistically significant at the 1% level, validating the long-run link in the empirical equation. The results of the cointegration test are shown in Table 3.

Table 3 Results of long-run cointegration: symmetric and asymmetric framework

long-run cointegration		$C_{overall}$		t_{DV}		F_{IDV}	
APRIL		8.362***		-6.838***		7.404***	
NARDL		7.314***		-5.547***		8.922***	
Critical value: K=5	1%		5%		10%		
	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	
Pesaran Pesaran, Shin (75)	5.095	6.77	3.673	5.002	3.087	4.277	
Narayan Narayan (76)	-3.96	-5.13	-3.41	-4.52	-3.13	-4.21	
Sam, McNown (93)	3.58	5.91	2.46	4.18	2	3.47	

4.2. Long-run and short-run estimation: symmetric and asymmetric assessment

In the long and short term, the ARDL (NARDL) financial development coefficient was positive and statistically significant at a1%, indicating that monetary expansion promotes environmental deterioration in Bangladesh. Our results are consistent with prior research (9, 94-97). It is known that increasing economies place a greater burden on the natural environment, as shown by the study results. Increased pollution and loss of natural resources are consequences of a growing middle class in emerging countries. According to studies undertaken by the World Bank, the status of the environment is adversely impacted by economic growth. Only a few factors, including credit growth, FDI, and stock market valuation, were studied in this study. All of these were associated with increased ecological stress. According to the research, economic expansion has a greater impact on environmental degradation in low-income countries than high-income countries. This is likely because low-income nations depend more on natural resources and have fewer resources to avoid environmental damage (10, 98, 99). The findings of this study highlight the necessity for governmental action to promote sustainable development. Without these protections, economic expansion will continue to harm the environment, impacting both the present and the future. It is considered that the wealth effect, which increases energy consumption and CO2 emissions, is one way FD hurts the environment. Alsahlawi and Chebbi (100) state that FD substantially degrades ecological quality. According to (101-105), a well-developed financial system is necessary for financing new and developing firms, which increases energy consumption, greenhouse gas emissions, and environmental quality. Additionally, the financial sector offers expanded financial services, such as financing for autos and other mechanical equipment that may raise energy consumption and carbon emissions. FD costs energy and has environmental effects, as shown by Mukhtarov and Mikayalov (106). FD increases energy consumption and economic development by providing low-cost and accessible finance to homes and companies, which may increase carbon emissions and environmental damage (18, 107, 108).

The coefficients of REC revealed negatively associated with environmental degradation; that is, REC declines the carbon emission in the long run (a coefficient of -0.1829) and short-run (a coefficient of -0.025). Using renewable energy sources has a major effect on Bangladesh's carbon footprint. The country's energy consumption has been rising at a frightening pace with the country's fast industrialization and urbanization. Yet, conventional energy sources like coal, oil, and gas have led to huge carbon emissions that pose serious environmental hazards. Changing to renewable energy sources like solar, wind, and hydroelectricity may drastically decrease greenhouse gas emissions. As a result, millions of people in remote places will have better access to consistent electricity. Bangladesh has launched several sustainable development initiatives in recent years to promote green growth and increase the percentage of renewable energy in the country's national resource mix. The government also establishes laws and incentives to promote private investment toward renewable energy projects to meet the 10% renewables-based installed capacity targets by 2020 and 20% by 2030. Bangladesh must embrace more sustainable technology to meet it's expanding energy needs without further damaging the environment or substantially contributing to global warming via CO2 emissions from traditional fuel usage.

Table 4 Long-run and short-run coefficients: ARDL and NARDL test

	Coefficient	**t-stat**	**std. error**		**Coefficient**	**t-stat**	**std. error**
LONG RUN							
FD	-0.0402	0.0107	-3.757	FD^+	-0.0741	0.0103	-7.1941
REC	-0.1829	0.0033	-55.4242	FD^-	-0.086	0.0071	-12.1126
FDI	-0.1307	0.0077	-16.974	REC	-0.0631	0.009	-7.0111
TO	-0.121	0.0024	-50.4166	REC	-0.0747	0.0035	-21.3428
				FDI	0.0744	0.0067	11.1044
				TO	0.0215	0.0066	3.2575
WLR					8.78		
WLR					8.604		
Short-run							
FD	0.0281	0.0117	2.4017	FD^+	-0.0146	0.0021	-6.9523
REC	-0.025	0.0111	-2.2522	FD^-	-0.0654	0.0081	-8.074
FDI	-0.0669	0.0038	-17.6052	REC	0.0229	0.0096	2.3854
TO	-0.1086	0.0062	-17.5161	REC	0.0567	0.0069	8.2173
				FDI	0.0271	0.007	3.8714
				TO	-0.0146	0.0021	-6.9523
ECM_{t-1}	-0.116695	0.0924	-1.2629329		-0.6612	0.1971	-3.3548
WSR					8.182		
WSR					3.167		
$x^2_{Autocorrelation}$	0.714				0.858		
$x^2_{Heteroskedasticity}$	0.722				0.519		
$x^2_{Normality}$	0.625				0.731		
x^2_{RESET}	0.877				0.89		

In addition, FDI attracts INVESTMENT, which enables growth that is heavy on energy use and harmful to the environment (109). In both the long- and short-term analysis, the coefficient of trade openness demonstrated a positive connection with environmental degradation, suggesting that the economy may increase international trade liberalization at the expense of environmental deterioration (110-113). Free Trade has been shown to positively affect the environment, including the potential to halt degradation. Several studies have shown that countries with open trade

policies are more likely to experience absolute and relative environmental degradation. More convenient access to trade may affect ecosystems in a variety of ways. One major factor is the so-called "pollution haven" effect, which occurs when businesses seek lower operating expenses by relocating to countries with laxer regulations on using natural resources. This might lead to increased pollution in the host nation and the loss of jobs and investment in the country of origin. The need for natural resources is also a major factor (114, 115). Natural resources such as timber, minerals, and oil often increase demand once a country opens its market to global trade. It is possible that the increased demand for these resources would lead to their overexploitation, which might have a severe impact on the local ecology (116).

Regarding the environment, trade liberalization may affect things in a roundabout way. For instance, economic development brought on by trade liberalization may strain the world's natural resources and lead to an uptick in pollution levels. Moreover, FDI flows linked with trade liberalization may often be channeled towards environmentally intensive businesses like mining and manufacturing. Globally, more unrestrained commerce is linked to less environmental destruction.

Both symmetric and asymmetric assessments found that FDI has a catalytic role in the degradation of environmental quality, supporting the pollution haven hypothesis as an explanation for the persistence of FDI inflows (18, 35, 97, 117-119). It has been argued that FDI may help stimulate economic growth and development. There is mounting evidence, however, that FDI may have unfavorable effects on the natural world. Foreign direct investment (FDI) has been linked in several studies to worsening environmental conditions, especially in poorer nations. The environment may suffer as a result of FDI for several different reasons. To begin, foreign direct investment (FDI) often results in adopting manufacturing methods and technologies that are more resource-intensive and polluting than those already used in the nation of origin (120-122). Second, foreign direct investment (FDI) might cause the exploitation of otherwise untapped natural resources. There is a risk of environmental damage and habitat loss as a consequence. Third, urbanization might speed up when factories and other city infrastructures are built by corporations with foreign direct investment. Because of this, pollution levels may rise, and scarce resources may become even more stressed. It's concerning that FDI has such unfavorable effects on the natural world. It's important to remember that these results aren't necessarily predetermined. The negative consequences of FDI on the environment may be lessened or even prevented with legislation and control (123).

5. Discussion

Foreign direct investment (FDI) has significantly affected Bangladesh's economic growth and development. As the country's energy consumption primarily depends on fossil fuels, this has also significantly increased carbon emissions. This article will examine the impact of foreign direct investment (FDI) on carbon emissions in Bangladesh, as well as the steps that can be taken to mitigate its negative effects. In recent decades, FDI has been a significant source of investment in Bangladesh, particularly in the energy and manufacturing sectors. However, the increase in FDI has also led to a substantial rise in energy consumption and carbon emissions. The energy sector is responsible for most of Bangladesh's carbon dioxide emissions, which increased from 34 million metric tons in 2000 to 91 million in 2016. The reliance on fossil fuels for energy production significantly contributes to the increase in carbon emissions. Thermal power facilities that use coal and natural gas for fuel predominate in Bangladesh's power sector. This has resulted in a substantial increase in greenhouse gas emissions, a significant contributor to climate change.

FDI can have a positive effect on carbon emissions, however. For example, foreign investors can help reduce emissions by introducing new technologies and practices. This includes the development of solar, wind, and hydropower initiatives, which can help reduce the nation's reliance on fossil fuels and carbon emissions. FDI can also contribute to developing energy-efficient technologies and practices that help reduce energy consumption and greenhouse gas emissions. This includes the use of energy-efficient manufacturing equipment, the implementation of energy management systems, and the construction of green structures. To mitigate the negative impact of FDI on carbon emissions, the Bangladeshi government must implement policies that foster sustainable development. This includes encouraging renewable energy development, promoting energy efficiency, and providing incentives for foreign investors to invest in low-carbon initiatives. The government could, for instance, implement tax incentives and subsidies for renewable energy projects, encourage foreign investors to invest in energy-efficient technologies and promote sustainable urbanization. Additionally, the government could collaborate with foreign investors to develop sustainability plans that include carbon emission reduction measures. FDI has significantly contributed to Bangladesh's economic development, but it has also contributed to the country's carbon emissions. To mitigate the negative impact of FDI on carbon emissions, the government must implement policies that promote sustainable development, such as the development of renewable energy, energy efficiency measures, and sustainable urbanization. This will promote long-term economic growth and development in addition to reducing carbon emissions(124).

Bangladesh, one of the most densely populated and rapidly developing countries in the world, has the potential to reduce carbon emissions significantly through the use of renewable energy. The nation's energy sector is highly dependent on fossil fuels, which has led to a substantial increase in carbon emissions and contributed to global climate change. This article will examine the impact of renewable energy consumption on Bangladesh's carbon emissions. Renewable energy, such as solar, wind, and hydropower, is a sustainable and environmentally friendly alternative to traditional fossil fuels. The government of Bangladesh recognizes the potential of renewable energy. It aims to produce 10% of the nation's electricity from renewable sources by 2021. Bangladesh has the potential to reduce carbon emissions through renewable energy substantially. According to the International Renewable Energy Agency (IRENA), Bangladesh's use of renewable energy could reduce carbon dioxide emissions by 2,2 million tons by 2030. Additionally, the development of renewable energy initiatives can aid in creating new employment and promoting economic expansion, particularly in rural areas. For instance, the development of off-grid solar energy systems can provide access to electricity in areas not connected to the national infrastructure, thereby improving the living conditions of those who reside there.

In addition, renewable energy can help reduce the country's reliance on imported fossil fuels, enhancing energy security and decreasing its susceptibility to external energy disruptions. Several obstacles must be overcome to expedite the adoption of renewable energy in Bangladesh. One of the greatest obstacles is the lack of financing for renewable energy projects, particularly minor and medium-sized initiatives. This has led to a paucity of investment in renewable energy, which has hampered the sector's development. Another obstacle is the lack of technical expertise and infrastructure for renewable energy initiatives, particularly in rural areas. This has resulted in a lack of public awareness and comprehension regarding renewable energy, which has delayed the adoption of renewable energy technologies(125). To surmount these obstacles, the Bangladeshi government must implement policies and initiatives that encourage the development of renewable energy projects. This includes providing financial incentives and subsidies for renewable energy projects, improving access to financing for small and medium-sized projects, and developing technical expertise and infrastructure for renewable energy projects. The implementation of renewable energy has the potential to substantially reduce carbon emissions in Bangladesh and foster sustainable economic growth. However, several obstacles must be overcome to accelerate the adoption of renewable energy technologies. The government of Bangladesh must implement policies and initiatives that encourage the development of renewable energy projects to resolve these challenges and promote sustainable development(126).

6. Conclusion

The findings of this study indicate that there is a nexus between financial development and carbon emission. Specifically, the positive relationship between the two variables suggests that increased levels of financial development can lead to higher levels of carbon emissions. Therefore, policymakers should consider practical measures to promote economic growth while not overlooking their environmental responsibilities. This could include raising awareness of energy efficiency policies that would reduce the effects of carbon emissions to ensure both sustainable economic growth and a healthy environment for future generations.

Financial developments have the potential to accelerate renewable energy consumption, which in turn can reduce carbon emissions. The growth of green bonds and other sustainable investments indicates that investors recognize the importance of transitioning to a low-carbon economy. However, governments and businesses need to continue supporting policies and initiatives promoting renewable energy adoption. The benefits of renewable energy consumption extend far beyond reducing carbon emissions. It also creates new jobs, promotes innovation, increases energy security and provides access to affordable electricity in remote areas. It's time for individuals and organizations worldwide to take action toward a more sustainable future by investing in renewable energy sources. Doing so contributes positively to our environment and creates a better world for generations ahead.

Bangladesh, which is extremely susceptible to the effects of climate change, faces a major challenge in reducing carbon emissions. To address this issue, the government of Bangladesh must implement policies and initiatives that promote both economic growth and the use of renewable energy. Here are a few policy recommendations: First, the government can provide tax credits and subsidies to encourage private sector investment in renewable energy projects. This can stimulate the development of the renewable energy industry and reduce the nation's reliance on fossil fuels. Second, a feed-in-tariff policy is a mechanism that incentivizes the production of renewable energy by guaranteeing a fixed rate for renewable electricity. Implementing a feed-in-tariff policy can increase investment in renewable energy initiatives and foster the growth of the renewable energy industry. Third, the government can support the development of infrastructure for renewable energy, such as transmission lines and energy storage systems. This can help facilitate the integration of renewable energy into the national grid and expand the renewable energy sector's overall capacity. Fourth, the government can promote energy efficiency by offering financial incentives for adopting energy-efficient

technologies, such as LED illumination and energy-efficient appliances. This can aid in reducing global energy consumption and promoting the use of renewable energy sources.

In conclusion, reducing carbon emissions in Bangladesh requires a concerted effort to promote economic growth and renewable energy use. The government can implement policies and initiatives that incentivize private sector investment in renewable energy, support the development of renewable energy infrastructure, and promote the creation of green bonds. Bangladesh can reduce its reliance on fossil fuels, increase energy security, and contribute to global efforts to mitigate climate change by taking these steps.

Compliance with ethical standards

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There is no conflict of interest.

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