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Do Foreign Direct Investment, Urban Population, Trade Openness, CO_2 and GDP Influence the Renewable Energy Consumption? Case of Bangladesh Using the ARDL Approach

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Abstract

Together with management skills, the flow of foreign direct investment (FDI) from multinational corporations into their host countries often occurs concurrently with the transfer of information and technology. With the aid of time series data extending from 1972 to 2021, the primary goal of this article is to demonstrate the relationship between FDI, GDP, trade openness, population growth, and CO2 with renewable energy usage in Bangladesh. The ARDL test validates a long-term relationship between the variables, while the heteroscedasticity test demonstrates a homoscedastic relationship. We discovered the data has normalcy in skewness and kurtosis using the Jarque-Bera normality test. The CUSUMSQ test was used to determine the stability of our variables, and the results show that they are stable. Investment in the renewable energy sector should be increased by considering policies to attract more FDI.

Keywords: *ARDL, Bangladesh, CO2 emissions, Renewable Energy Consumption, FDI*

1. Introduction

In order to meet the difficulties of energy access, the rising demand, and to improve energy security, many developing economies are required to strengthen their energy producing capacities (Saha, 2025). There is a widespread understanding of the importance of using renewable energy and expanding its deployment to draw attention to the most pressing global issues, starting with climate change, air pollution, creating new economic opportunities, and concluding with giving many people's accesses to energy worldwide.

About the creation of renewable energy, FDI serves as the main source of funding and a crucial channel for transferring more effective technology methods for developing nations' economies. In addition to other forms of funding, FDI plays a crucial role in economic development (Sun, 2002; Saha, 2024). FDI is regarded as a speedy and effective way to transfer best practices across international borders, including those related to technology, the environment, and socioeconomic norms.

Several academics claimed that knowledge and better practices are the only ways for multinational corporations to get a competitive advantage, which is why FDI occurs environmental and productivity spill overs. As a result, FDI has evolved into a dynamic component of the majority of national economic agendas (Saha et al., 2022)

As a result, many developing nations are working to increase foreign direct investment, notably in the rapidly rising worldwide sector of renewable energy.

Bangladesh, like many developing countries, is facing a dual challenge of economic development and environmental sustainability (Saha, 2022). While economic growth is essential for poverty alleviation and improving the standard of living, it should not come at the expense of environmental degradation. Renewable energy has been recognized as a crucial element of long-term growth in Bangladesh. By 2021, the nation wants to generate 10% of all its electricity from renewable sources and 15% by 2025 (Bangladesh Power Division, 2021). However, the country faces significant challenges in achieving these targets, including limited financial resources, technological barriers, and a lack of expertise (Saha, 2025; Saha, 2023).

Foreign direct investment (FDI) has been identified as a significant source of capital, technology, and expertise in many developing countries, including Bangladesh. At the same time, FDI can also have positive spillover effects on the environment, including the adoption of cleaner technologies and practices (Dinda, 2020; Saha, 2023). In recent years, the connection between FDI and the utilization of renewable energy has drawn more and more attention. Some studies have suggested that FDI can stimulate the adoption of renewable energy by providing financial resources and technological expertise (Sadorsky, 2017; Balsalobre-Lorente et al., 2019). Some researchers have discovered a conflict between FDI and the use of renewable energy, suggesting that FDI may increase energy demand and, hence, fossil fuel consumption (Bilgili et al., 2017; Pao & Tsai, 2011).

The purpose of this study is to look into the connection between FDI and renewable energy use in Bangladesh. This study aims to investigate the relationship between foreign direct investment and renewable energy consumption in Bangladesh. In the case of Bangladesh, this study especially examines the relationship between FDI, urban population, trade openness, CO2, and renewable energy use. This study adds to the body of literature by identifying the macroeconomic factors that affect the consumption of renewable energy. The theoretical context, justification, and goal of this investigation are covered in the first section of the study. The study's subsequent sections are organized as follows:

The "Literature Review" section of this study is the second component. The literature review section should exhibit in-depth subject expertise and offer justifications for the study topic. The purpose of the chapter on the literature review is to outline several theoretical views and, from them, to create a theoretical case.

"Research Design" is the third section. This section should provide a description of the research's design and methodology.

The fourth part of this paper is "Results and Discussions". This part details all the outcomes of this research and interprets the results with the help of statistical tools and econometric analysis.

Finally, the fifth part features the conclusion and policy recommendations.

2. Rationale

For a number of reasons, it is crucial to investigate the connections between Bangladesh's FDI, urban population, trade openness, CO2 emissions, GDP, and use of renewable energy sources. **Firstly**, Bangladesh is a developing nation with an expanding economy that relies significantly on fossil fuels to provide its electricity. To decrease its carbon footprint and lessen the effects of climate change, the nation has set ambitious goals to increase the amount of renewable energy in its energy mix. Therefore, it is crucial for decision-makers and investors in the energy sector to comprehend the elements that affect the use of renewable energy in the nation.

Secondly, It is anticipated that FDI, urbanization, and trade openness would all have an impact on Bangladesh's economic growth and development. In order to ensure that economic growth and development are accomplished in a sustainable manner, it is crucial to understand the relationship between these elements and the usage of renewable energy.

Thirdly, Due to its geographic location and dense population, Bangladesh is particularly sensitive to the effects of climate change, which is largely a result of CO2 emissions. Hence, the nation has made reducing CO2 emissions through the use of renewable energy sources a priority**.**

Finally, The study's use of the ARDL technique is particularly pertinent since it enables the analysis of long-term correlations between the important variables. This is

significant when discussing the use of renewable energy because it may take several years for the effects of policy changes and investments in the field to manifest.

Overall, the ARDL approach study of the association between FDI, urban population, trade openness, CO2 emissions, GDP, and renewable energy consumption in Bangladesh is crucial for informing policymaking and investment decisions in the energy sector, as well as for ensuring that economic growth and development are accomplished in a sustainable way.

2.1 Objectives of the study

The study's primary goal is to assess the long-term and short-term effects of population increase, energy consumption, trade openness, foreign direct investment, and economic growth on carbon emissions for the years 1972 to 2021.

The specific objectives of the study are:

1. Here, we choose five factors that may be related to renewable energy consumption in Bangladesh in order to examine the extent of its use. Which are: From 1972 to 2021: Foreign Direct Investment, Urban Population Growth, Trade, CO2 and GDP.
2. Using an ARDL approach, we look at how Foreign Direct Investment, Urban Population Growth, Trade openness,CO2 and GDP affect renewable energy consumption.

3. Literature Review

Bangladesh is a developing nation whose economy is expanding quickly. However, because of its significant reliance on conventional energy sources like coal and natural gas, the nation is currently experiencing serious energy shortages. The Bangladeshi government is encouraging the use of renewable energy sources there as a solution to this problem. Another important source of investment in the nation is foreign direct investment (FDI). In order to examine the connection between foreign direct investment and renewable energy usage in Bangladesh, this research will evaluate the pertinent literature.

Herman (2013) examined the extent to which the Chilean government's policies on renewable energy and associated government organizations create a stable foundation for FDI in sizable renewable energy projects. After that summary, a thorough examination of Chile's emerging renewable energy sector is provided. This analysis takes into account the requirement for the creation of a renewable energy technopole, which may drive away more and more specialists in the area.

The use of time series data spanning the years 1980 to 2015,**Khandker et al. (2018)** shown the link between FDI and Bangladesh's use of renewable energy. Our variables of interest have a bidirectional causal relationship, as shown by the Granger causality test,

and over the long run, as shown by the Johansen cointegration test. Using the Vector Error Correction Model, we were unable to identify any immediate causes between the variables (VECM).

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Kiliçarslan (2019) aimed to investigate the relationship between foreign direct investment (FDI) and the creation of renewable energy in Turkey as well as the BRICS countries of Brazil, Russia, India, China, and South Africa. The annual data from 1996 to 2015 are examined for this using the Pedroni co-integration test and the panel autoregressive distributed lag test**.**

Alshubiri et al. (2020) aimed to look into how OPEC's usage of green and non-green energy changed as the economy developed between 1990 and 2015. The data was acquired for 14 OPEC countries between 1990 and 2015 from the Green Growth Knowledge Platform Database and the World Development Indicators (WDI) of the World Bank. Environmental quality was impacted differently by domestic credit ratio and international direct investments (foreign financial development) (domestic financial development). Their main conclusions show that FDI lowers environmental quality in OPEC economies and behaves as a pollutant by increasing non-renewable CO2 emissions per person by about 0.0224% and reducing non-renewable energy consumption traits. Hence the non-green growth theory is supported by the link between FDI's renewable and non-renewable components.

Fan & Hao (2020) compared the relationship between FDI, GDP, and the use of renewable energy in 31 Chinese provinces between 2000 and 2015. The estimations use the impulse response function analysis, unit root test, vector error-correcting model, and Granger causality test to be more accurate. The empirical results show that the ratios of gross domestic product, foreign direct investment, and renewable energy use per person are in a stable, long-term equilibrium.

In 47 Sub-Saharan African nations, **Sarkodie et al. (2020)** employed panel data from 1990 to 2017 using a dynamic heterogeneous estimation approach. We were able to consider heterogeneity, a circumstance that may be widespread in countries with various economic and environmental policies, with the aid of the empirical methodology we used. The empirical results demonstrated that whereas an increase of 1% in the coupling impact of income level, governance, and renewable energy consumption increases climate change by 0.79%, an increase of 1% in the share of renewable energy reduces greenhouse gas emissions by as much as 35.32%. (95% Confidence interval).

Kang et al. (2021) aimed to examine the connection in a number of South Asian countries between urban population , carbon dioxide, trade openness , gross domestic product , foreign direct investment , and renewable energy . Fully modified ordinary

least square (FMOLS) and dynamic ordinary least square (DOLS) models were utilized in the study, which included annual data from 1990 to 2019. If the variables were stationary, the Im-Pesaran-Shin, Fisher PP, and Levin-Lin-Chu tests were run.

Some scholars have also identified potential negative impacts of renewable energy use on economic expansion, particularly in developing countries. For instance, a study by **Chen et al. (2018)** revealed that the use of renewable energy decreased economic growth in 18 Asian nations, including Bangladesh. Similarly, a study by **Baloch et al. (2019)** discovered that Pakistan's economic growth was negatively impacted by the use of renewable energy.

A study by **Shahbaz et al. (2017**) revealed that the use of renewable energy decreased FDI inflows to 80 nations, including Bangladesh. Similarly, a study by Ozturk and **Acaravci (2013)** discovered that the use of renewable energy impacted Turkey's FDI inflows negatively.

discovered that Turkey's FDI inflows were negatively impacted by the adoption of renewable energy. While some studies suggest a positive relationship, others indicate a negative relationship. The negative impact of FDI on the use of renewable energy may be attributed to the dominance of energy-intensive industries in the manufacturing and services sectors, which attract FDI inflows. The government of Bangladesh needs to address this issue by implementing policies that promote renewable energy and incentivize FDI inflows into the renewable energy sector. This can be achieved by providing financial incentives and technology transfer to companies investing in the renewable energy sector.

4. Data and Research Design

The secondary data was obtained from the World Bank's website's database of "World Development Indicators" (WDI). The World Bank Development Indicators are now the repository of all annual data. The data are collected after the bloody liberation war in 1971.For this reason, the sample period of 1972-2021 is adopted in this instance. Information about the variables used in the analysis is given in the Table 1:

Table 1: Data Sources

Symbol	Variables	Source
REC	Renewable Energy Consumption (% of total final energy consumption)	World Development Indicators (WDI)-
FDI	Foreign Direct Investment (Net inflow a% of GDP)	World Development Indicators (WDI)-
UP	Urban Population Growth (annual %)	World Development Indicators (WDI)-
TR	Trade Openness	World Development Indicators (WDI)-
CO2	CO2 (metric tons per capita)	World Development Indicators (WDI)-
GDP	Gross Domestic Product	World Development Indicators (WDI)-

4.1 Model Specification

The following regression model for the study's time series data can be created:

$$REC_t = \beta_0 + \beta_1 FDI_t + \beta_2 UP_t + \beta_3 TR_t + \beta_4 CO2_t + \beta_5 GDP_t + \epsilon_t \quad (1)$$

To examine how the variables' co-integrating relationships affect one another, the bound test is run. The predicted F-statistic value at the 5% level of significance supports the long-term association between the variables. The estimated value of the F-statistic is calculated by comparing the values of the upper and lower critical bounds (Pesaran et al. 2001). The null hypothesis that there is no cointegration among the variables is refuted if the estimated F-value is greater than 1.

The statistic value is still above the upper bound's critical value. If the computed value remains below the lower bound critical value, the finding also supports the null hypothesis of no cointegration. Conversely, the inference is deemed invalid if the estimated F-statistics value lies inside the higher and lower critical boundaries. Two assumptions are outlined below for the estimation of the long-term connection among the variables:

H_0: σ1 = σ2 = σ3 = σ4 = σ5 = 0

H_1: σ1 ≠ σ2 ≠ σ3 ≠ σ4 ≠ σ5 = 0

The following is the model's limits testing equation::

$$\Delta REC = \alpha_0 + \sigma_1 REC_{t-i} + \sigma_2 FDI_{t-i} + \sigma_3 UP_{t-i} + \sigma_4 TR_{t-i} + \sigma_5 CO2_{t-i} + \sigma_6 GDP_{t-i} + \sum_{i=1}^{r} \beta_1 FDI_{t-i} + \sum_{i=1}^{r} \beta_2 UP_{t-i} + \sum_{i=1}^{r} \beta_3 TR_{t-i} + \sum_{i=1}^{r} \beta_4 CO2_{t-i} + \sum_{i=1}^{r} \beta_5 GDP_{t-i} + \varepsilon_t \quad (2)$$

4.2 Autoregressive Distributed Lag Model

Cointegration is investigated using the Autoregressive Distributed Lag (ARDL) method. The primary purpose of the ARDL model is to look at the short- and long-term relationships between the variables being studied. This method has some advantages over existing cointegration analysis strategies. According to Pesaran et al., the ARDL model can be used for small sample sizes with mixed integration orders, such as I (0) and I (1). Additionally, this cointegration technique is employed with different lag lengths for the dependent and independent variables, and the long-run estimations are unbiased despite the model's inclusion of endogenous regressors. (Odhiambo 2009).

Assuming there was cointegration among the variables, the following is how the ARDL long term model can be calculated:

$$REC = \beta_0 + \sum_{i=1}^{m} \beta_{1i} REC_{t-i} + \sum_{i=1}^{m} \beta_{2i} FDI_{t-i} + \sum_{i=1}^{m} \beta_{3i} UP_{t-i} + \sum_{i=1}^{m} \beta_{4i} TR_{t-i} + \sum_{i=1}^{m} \beta_{5i} CO2_{t-i} + \sum_{i=1}^{m} \beta_{6i} GDP_{t-i} + \varepsilon_t \quad (3)$$

5. Results and Discussions

5.1 Unit Root Test

When we use an autoregressive distributed lag model, a variable does not have to become stationary at the level. This model can make use of both stationary and non-stationary variables. Both non-stationary time series and time series with a mixed order of integration can use it. Next, we want to make sure that all of our variables are stationary. Because of this, we use one of the mostly used econometric method namely, Augmented Dickey-Fuller (ADF) test of stationarity.

Table 2. Augmented Dickey Fuller Test

Variable	Constant & trend		Constant	
	Level	1st difference	Level	1st difference
REC	-3.281	-3.815**	-4.072*	-1.284
FDI	-1.785	-5.760***	-1.004	-5.824*
UP	-2.641	-4.191***	-1.206	-4.228*
TR	-1.696	-5.541***	-0.110	-5.471*
CO2	-0.400	-3.815**	6.128**	-1.284
GDP	-12.760***	-20.771***	-1.304	-21.345***

*, **, *** indicates 1%, 5%, and 10% level of significance.

Table 3 represents the estimated result for ADF test statistics and associated critical value for different acceptable levels. We cannot rule out this null hypothesis if the associated test statistics are higher than the acceptable threshold of critical value maximum (10%) and the data has unit root.

On the other hand, we reject the null hypothesis and can state that the variable is stationary if the associated test statistics are less than the acceptable threshold of critical value maximum (10%). In light of this requirement, the FDI, UP, Trade, and GDP variables are shown in the above table to be stationary at first difference and the REC and CO2 variables to be stationary at level in the ADF test. The findings demonstrate that the critical values—which are at the l%, 5%, and 10% significance levels—are higher than the accepted norm.

5.2 ARDL Bound Test

The British-Iranian economist Pesaran (2001) first proposed the ARDL bound test approach, which we utilize in this work to examine the long-run correlations among variables. In their study, Pesaran et al. (2001), they first do limits tests in the unrestricted model, or more specifically, an ARDL model, and then they use the ARDL method to estimate level relations. They assume that I (0) or I (1) are the critical values

in their method for the bound test. I (0) serves as the case's lower bound critical value, and I serves as the case's upper bound critical value (1). Table 4 displays the outcomes of the ARDL bound test for both models.

Table 3. ARDL Bounds Test

ARDL Model		
Model	**F-Statistics**	**K**
	7.885	5
Critical Values	Lower Bound I (0)	Upper bound I (1)
10% significance Level	2.26	3.35
5% significance Level	2.62	3.79
1% significance Level	3.41	4.68

If the F-statistic (7.885) is more than the upper bound I(1) critical value for 10%, 5%, and 1%, which is a tolerable level of significance, we reject the null hypothesis that the variables do not have a long-term association. If we can reject the null hypothesis, we can conclude that there is a significant long-term relationship between the variables.

5.3 ARDL Long-Run Model

A long-run relationship means that the models have some fixed mean value, but in the short run, the variable would be fluctuating among this but its inherent tendency to converge to its long nm fixed value.

For the optimal lag choose for ARDL bound test we use Akaike Information Criteria (AIC). We set the maximum lag at 3 for both the dependent and explanatory variables since the data we collected are of comparative short duration (32 years), and the Table 5 result implies that the optimum lag should be taken as 3.

Table 4. Estimated ARDL Long-run model

Variable	Coefficient	St. Error	t-statistic	P value
REC	-0.4462236	0.074158	-6.02	0.000
FDI	-9.226937	1.911768	-4.83	0.001
UP	-0.2632016	0.9578974	-0.27	0.790
TR	0.3956155	0.1131616	3.50	0.008
CO2	-49.84497	7.028912	-7.09	0.000
GDP	-4.174208	0.7744755	-5.39	0.001

The variables' long-run equilibrium connection, as approximated using the ARDL (2,2,3,1,3,2). Table 5 shows that there is a long-term, negative, and substantial relationship between foreign direct investment, CO2, and GDP. Renewable energy use is a dependent variable. On the other hand, commerce ultimately has a favorable and

considerable effect on the usage of renewable energy. Urbanization has a negative and negligible effect on the use of renewable energy.

The long-run model we get is shown in equation (4):

REC = -9.2269*FDI -0.2632*UP + 0.3956*TR – 49.8449*CO2 -4.1742*GDP + ECT(y) (4)

The error correction term that describes how quickly an equilibrium will adapt. Asymmetry for ARDL is corrected for the coefficient of - 0.4462236 as a consequence of the investigation. The results of the long-term ARDL analysis demonstrate that Bangladesh's utilization of renewable energy is negatively impacted by foreign direct investment. According to the investigated data, FDI influx has a negative long-term impact on renewable energy usage of up to 9.2269%. According to the investigated trade openness statistics, a 1% increase over time will raise Bangladesh's usage of renewable energy by 0.3956%.

We also looked at the long-term relationship between CO2 emissions and the use of renewable energy. Our analysis demonstrates that CO2 has a detrimental effect on increasing the consumption of renewable energy. Over time, a 1% increase in CO2 results in a 49.8449% drop in the consumption of renewable energy. GDP has a negative long-term impact on the utilization of renewable energy. According to our data, the usage of renewable energy reduces by 4.1742% for every 1% growth in GDP. This demonstrates unequivocally that, in Bangladesh's case, rising GDP has a negative influence on the use of renewable energy.

The acronym "ECT" stands for error correction terminology, which gauges adjustment speed. The studied data show that ECT is statistically significant and negative. According to the ECT term, the long-term imbalance of 44.622% is corrected. According to the R-squared value, the explanatory factors used in this study are responsible for 96% of the variability in the dependent variable.

5.4 ARDL Short-Run Model

Table 6 presents the short-term outcomes. We discover that FDI has a short-term, statistically significant positive impact on the usage of renewable energy. In the short term, a 1% increase in FDI results in a 2.7592% rise in the usage of renewable energy. At 1% level, the coefficient is substantial.

The findings indicate that urban population has a detrimental impact on the use of renewable energy. In the short run, a 1% increase in urban population results in a 3.8845% decrease in renewable energy use, and the coefficient is statistically significant at that level. The transaction has a detrimental effect on the utilization of renewable energy. The analysis demonstrates that a 1% increase in commerce during the same year results in a statistically significant 0.1962% decrease in the consumption of renewable energy. The consumption of renewable energy is negatively impacted by CO2; at a 1% significance level, a 1% increase in CO2 reduces renewable energy

consumption by 63.2926%. The consumption of renewable energy is positively impacted by gross domestic product (GDP). At a 1% level of importance, a 1% rise in GDP results in a 1.3599% increase in the usage of renewable energy.

Table 5. Estimated ARDL Short-run model

Variable	Coefficient	St. Error	t-statistic	P value
REC	0.5594187	0.2063094	2.71	0.027
FDI	2.759253	0.6496411	4.25	0.003
UP	-3.884511	0.9855699	-3.94	0.004
TR	-0.1962191	0.0582767	-3.37	0.010
CO2	-63.29259	15.17084	-4.17	0.003
GDP	1.359898	0.3778118	3.60	0.007

6. Diagnostic tests

6.1 Heteroscedasticity and Normality test

In this study, we have performed heteroscedasticity (Breusch-Pegan/Cook-Weisberg Test) and normality test (Jarque-Bera Test) to evaluate the stability and fitness of our model.

The null hypotheses for the diagnostic tests are given as follows:
For the heteroscedasticity test: Ho: Homoscedasticity is present.
For normality test: Ho: The residuals are normally distributed.

Table 6. Results of diagnostic tests

Test type **Obtained**	**Test statistic**	**Value**	**p-value**
Heteroscedasticity Test (Breusch-Pegan/Cook-Weisberg Test)	F-statistic	1.30	0.2546
Normality Test (Jarque-Bera Test)	JB-statistic	0.1782	0.9148

According to the aforementioned hypothesis, the chi-squared value is not significant at the 5% level of significance, as can be seen in the Table, which displays the results of the Breusch–Pagan test of heteroscedasticity. We cannot rule out the other theory that, variables do not have heteroscedasticity. So, we conclude that the variables we have taken do not have heteroscedasticity.

The above table also shows the results of the J-B normality test. The t-statistic 1s 0.1782, which is closer to zero and the p-value is 0.9148 which is greater than 0.05 (i.e. p>0.05) so we cannot reject the null hypothesis. So, with the empirical results, we conclude the data has normality in skewness and kurtosis.

6.2 Stability of the model: CUSUM and CUSUMSQ

As recommended by Pesaran & Pesaran, we utilize the cumulative sum of square (CUSUMSQ) test to check for stability in the aforementioned model (1997). In the following figure, the CUSUMSQ statistic is shown graphically:

MODEL STABILITY TEST GRAPHS OF CUSUM AND SQUARE OF CUSUM

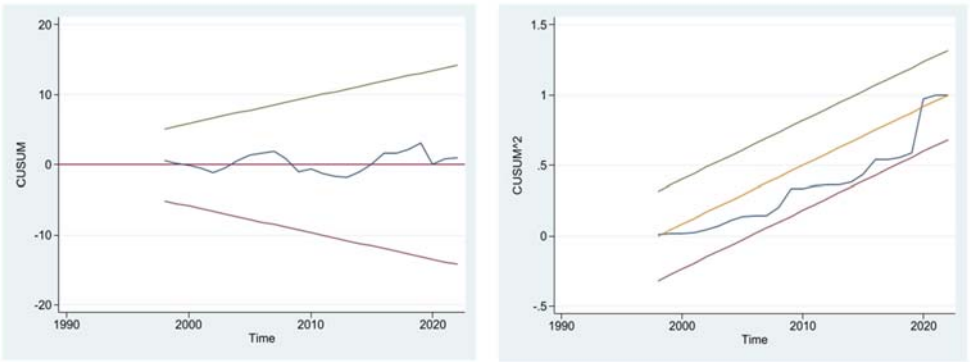

Figure 1: CUSUM and CUSUM square
Source: Author Calculations

The Cumulative Sum of Squares (CUSUM) test is a statistical test used to detect structural breaks or changes in the coefficients of an ARDL model. The ARDL model is a type of regression model used for analyzing time series data. It allows for the inclusion of both stationary and non-stationary variables in the same model. In the ARDL model, the dependent variable is regressed on a set of lagged independent variables and current values of the independent variables.

The findings shown in the figure demonstrates that the plot of the CUSUMSQ statistics is within the essential range of the 5% significant threshold for parameter stability, indicating that the coefficients are stable. Consequently, this data demonstrates the model's stability and the absence of a systematic change in the coefficients across the research period at a significance level of 5%.

7. Conclusion and Policy Recommendations

In the context of Bangladesh, the current study examines the long- and short-term relationships between economic growth, energy consumption, trade, foreign direct investment, and population with CO2 emissions. The method used to establish this link is known as the ARDL bound test approach. Annual time series data from 1990 to 2021 were used for the study. Empirical findings show a link between the variables under study over the long and short terms.

To resolve stationarity difficulties with the study's data, the ADF test is applied. The study's findings show that the series, which are of mixed integrating order and are hence I(0) and I(l), are not stationary at 1(2) The ARDL model is easier to utilize because the time series properties have a mix integrating order. The research uses a range of diagnostic techniques to show the absence of normality, autocorrelation, and heteroskedasticity concerns.

The long-term relationship's findings are in line with the findings of the empirical study. In the long run, there is a significant positive correlation between economic expansion and environmental deterioration. Manufacturing processes have a beneficial impact on CO2 emissions since the industrial sector is mostly dependent on fossil fuels that emit carbon. Bangladesh's expanding economic activity needs a higher demand for energy, which is more dependent on fossil fuels, leading to an increase in CO2 emissions. This is because Bangladesh is a developing country. Trade has a positive long run impact on carbon emission which complies with the previous analyses.

Moreover, the results we get from our ARDL analysis reveals that FDI has a detrimental effect on Bangladesh's CO2 emissions over the long and short terms. However, both in the short and long terms, population growth has a major positive impact on rising CO2 emissions.

It is crucial to pay attention to the negative correlation between Bangladesh's use of renewable energy, foreign direct investment (FDI), and gross domestic product (GDP). The limited availability and high cost of renewable energy sources have deterred foreign investors, resulting in a negative impact on FDI. Additionally, Bangladesh's significant reliance on fossil fuels and poor infrastructure for renewable energy have had a detrimental impact on economic growth and slowed the development of the renewable energy sector, which has contributed to a negative correlation between renewable energy consumption and GDP. Creating a comprehensive framework for renewable energy policy, strengthening institutional capability, and offering suitable funding choices are necessary to address these issues. Expanding the use of renewable energy might help the nation's economy develop dramatically and lessen its reliance on fossil fuels, paving the way for a more sustainable future. Overall, the negative correlation between Bangladesh's renewable energy consumption, FDI, and GDP underlines the necessity for ongoing campaigns to encourage the use of renewable energy and sustainable development.

Based on the findings of the negative relationship between renewable energy consumption and foreign direct investment (FDI) and gross domestic product (GDP) in Bangladesh, the following policy implications can be suggested:

1. **Creation of a comprehensive framework for renewable energy policies:** Bangladesh needs to improve an extensive renewable energy policy creation of a comprehensive framework for renewable energy policies framework to promote renewable energy consumption and attract foreign investors. The policy framework should include measures to encourage investment in

renewable energy sources and provide incentives for renewable energy projects.

2. **Improvement of institutional capacity:** To promote renewable energy consumption and attract foreign investors, Bangladesh needs to improve its institutional capacity in the renewable energy sector. This includes improving the regulatory framework, enhancing the capacity of regulatory institutions, and providing training to stakeholders in the renewable energy sector.
3. **Provision of adequate financing options:** The high cost of renewable energy technologies is a standard barrier to the consumption of renewable energy in Bangladesh. Therefore, the government needs to provide adequate financing options for renewable energy projects, including tax incentives, subsidies, and low-interest loans.
4. **Promotion of public-private partnerships:** Public-private partnerships can play a vital role in promoting renewable energy consumption and attracting foreign investors. To take use of the knowledge and resources of the private sector, the government should encourage public-private partnerships in the renewable energy industry.
5. **Implementation of energy efficiency measures:** Energy efficiency measures can help reduce energy demand, leading to a reduction in energy consumption's detrimental effects on GDP. The government should implement energy efficiency measures, including building codes, energy-efficient appliances, and energy audits, to reduce energy demand and promote sustainable development.

These policy ramifications can draw international investment to the renewable energy sector while promoting sustainable development in Bangladesh.

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