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Sustainable Energy Demand in Bangladesh: The Influence of Financial and Political Factors through Marshallian Demand Function

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ABSTRACT

The study aims to consider the impact of economy, trade openness (TRD), political stability (POS), financial development (FD), and urbanization (URB) on the energy demand (ENU) of Bangladesh. Several techniques, including the ARDL bound test for cointegration, DOLS, FMOLS, and CCR, were used to check how changes in independent factors impacted the dependent parameter. The ARDL findings indicate a considerable encouraging correlation among GDP expansion, political stability, trade openness, urbanization, and ENU. A 1% rise in GDP, POS, TRD, and URB causes a long-term rise in energy utilization of 0.327%, 0.817%, 1.166%, and 1.775%, respectively. In contrast, the increase in FD has a substantial favorable correlation with ENU, with energy use anticipated to decrease by 0.192% in the long term for every 1% upsurge in FD. The reliability of the findings is further validated by multiple estimators, including FMOLS, DOLS, and CCR. The Pairwise Granger Causality assessment was adopted to show the causal connection among many components. The analysis advocates for the establishment of regulatory initiatives to encourage energy efficiency, enhance the use of green power, and invest in sustainable trade and urban planning to reduce energy use and attain sustainable cities and environments in Bangladesh.

Keywords: Trade Openness, Political Stability, Financial Development, Energy Demand, Bangladesh
JEL Classifications: Q41, Q43,Q56, O13, C32

1. INTRODUCTION

The modern period has significant challenges, such as ecological damage and energy use, which threaten the swift progress of the global economy such as the loss of Earth's resources, pollution, and climate disasters (Nazir et al., 2024). The limited availability of raw materials and escalating fuel prices in global markets present considerable hurdles for emerging economies such as Bangladesh in addressing rising expenses of energy production (Murshed, 2021; Rehman et al., 2024). The need for electricity is escalating significantly owing to industrial development, growing populations, government development initiatives, and rapid urbanization (Saleem et al., 2020). According to BP (2022), in 2021, primary consumption of energy rose by 5.8%, surpassing 2019 levels by 1.3%. Recent research by Raihan et al. (2022) identifies Bangladesh as a rapidly rising nation on a global scale. Furthermore, developing nations have not yet succeeded in this regard and continue to struggle with providing their populations with an unrestricted supply of energy. In 2000, approximately 32% of the Bangladeshi population had access to electricity; by 2020, this figure exceeded 96% (Islam, 2019). Bangladesh's energy consumption has increased throughout decades (Borsha et al., 2024). The worldwide expansion rate of primary electricity consumption has risen by 2.9%, nearly twice the average growth rate of 1.5% since 2011 (Hassan et al., 2025). Moreover, Asif and Munir (2007) anticipate significant increases in worldwide energy consumption in the coming decades. Therefore, less reliance on fossil fuels will result in improved energy performance, which will cut down on pollutants, energy use, and the need for alternative fossil fuels (Can et al., 2022). Bangladesh must mitigate the ecological effects of its dependence on fossil fuels while fulfilling its increasing energy requirements (Puri et al., 2025). Therefore, with this motive this paper attempts to observe the effect of stable politics, expansion in GDP, URB, TRD and FD on the ENU in Bangladesh.

Energy propels human existence and is vital for ongoing human advancement. The globe's need for energy is escalating due to population growth, urbanization, and industrialization (Sohail et al., 2022). In opposite, harmony in politics can improve the monetary performance of a country. Political unrest has been a prominent characteristic of Bangladesh since its inception in 1971 (Ahmed and Pulok, 2013). However, the nation confronts significant barriers to growth yet continues to sustain a commendable pace (Rahman and Rashid, 2018). The quest for a stable and growing economy has traditionally been paramount for both authorities and citizens, as they strive to enhance their lifestyles (Saqib et al., 2024). Bangladesh has demonstrated a robust history of expansion and growth, achieving an average annual increment in real GDP of 6.4% from 2010 to 2023, despite periods of heightened worldwide instability (World Bank, 2024). Moreover, liberalizing the economy is significant, as it can foster free trade, stimulate funding for green energy initiatives, and cut in expenditure connected with alternative energies by reducing tariffs and non-tariff trade barriers (Qing et al., 2024; Wang et al., 2024). Furthermore, it may result in greater demand for energy and loss of biodiversity, both of which exacerbate the environment's susceptibility (Hakimi and Hamdi, 2016).

Recently, research on financial development and energy has mostly overlooked their connection in developing nations, particularly in Bangladesh. Numerous scholars (Sadorsky, 2010; Ridwan et al., 2024a) assert that financial development augments consumption of energy through GDP growth. Certainly, a significant degree of growth in finance fosters the advancement of money markets, banking systems, and equity markets, thereby increasing the availability of capital to invest (Minier, 2009; Arezki, 2022). Farhani and Solarin (2017) shows that development in finances can also decrease energy demand. Furthermore, urbanization and industrialization are seen as fundamental determinants of a nation's energy use (Liu et al., 2017). Urban areas have greater energy intensity than rural areas, as urban inhabitants utilize larger amounts of resources, hence exerting strain on the fragile ecology (Yu et al., 2020). The ongoing expansion of urban ecosystems will significantly affect energy demand and consumption (Amin and Rahman, 2019).

In light of this context, it is plausible to assert that Bangladesh's current energy dynamics and conservation efforts lack the necessary cohesion to achieve environmentally friendly goals. Political uncertainties, financial development and trade openness on a clean energy future and emissions may affect Bangladesh's energy conservation measures. Consequently, legislative modification, including robust political stability and adequate investment for renewable energies, may be necessary for Bangladesh to achieve equitable growth. This is where the present research contributes. The research seeks to discuss the implication of expansion in finances and harmony in politics on green energy demand, together with the associated difficulties of political threat, urbanization, and increased GDP growth. Considering that other industrialized nations, including China and the USA (Zheng et al., 2024), are facing energy challenges, Bangladesh's backgrounds may provide a paradigm for the global community. Moreover, several industrialized nations are striving to advance green energy, however they encounter challenges in reforming their current regulations to facilitate an energy-driven financial system (Du et al., 2023). To accomplish our goal we have incorporated the fresh ARDL bound test to explore the effect of POS, GDP growth, URB, FD and TRD on ENU within Bangladesh. The primary conclusion of the study is that only financial development can diminish power consumption in Bangladesh. Conversely, it has been seen that the remaining elements may encourage greater electricity utilization. Alongside providing trustworthiness in ascertaining the ARDL model results, the FMOLS, DOLS, and CCR estimators were employed. Additionally, various diagnostic evaluations were implemented to verify that the studies validity. Lastly, the results of this investigation contain major repercussions for government officials, energy participants, and political activists seeking to promote long-term prosperity and tackle preserving energy issues in Bangladesh.

2. LITERATURE REVIEW

Though the dynamics of the contributing factors need to be fully clarified, current literature suggests that individual behaviors are to blame for the continuous energy consumption. This section of the research analyzed prior studies about the effects of GDP, urbanization, political stability, financial development, trade openness, and energy demand. The following part is categorized into categories to facilitate an integrated examination of these connections.

2.1. GDP and Energy

Multiple inquiries exploring the correlation within rise in GDP and energy demand across various locations have yielded contradictory results. For example, Oktavilia et al. (2025) analyze the correlation between GDP growth and energy use in E7 nations from 1992 to 2020. Utilizing Random Effect and PMG models, they demonstrate that GDP exerts large positive effects on energy use over time. However, GDP does not have any immediate impacts on ENU. Tran et al. (2022) point out the impact of GDP on ENU, utilizing panel data from 26 OECD nations spanning 1971 to 2014. Their outcome reveals that there is a GDP threshold. The implication of GDP on ENU and the path of the energy-growth causality rely on the GDP number at the start. Tang et al. (2024) observed the implication of GDP development and coal intensity on energy consumption in Pakistan from 2001 to 2020. They found that a rise in GDP expansion correlates with a surge in coal utilization. On the other hand, Magazzino et al. (2021) reviewed the correlation between energy use and economic growth using a dataset spanning over eighty years in Italy. They conduct a wavelet analysis and find no evidence of a long-term association between energy usage and economic progress. However, Qamruzzaman and Jianguo (2020) examined panel data from countries classified as lower-middle and upper-middle income. They concluded that low-income countries can enhance their green power usage. Moreover, Alam et al. (2017) investigate the causal relationship between ENU and GDP growth in Bangladesh utilizing data from 1980 to 2011. The study found that GDP causes more energy use.

2.2. Financial Development and Energy

As the economy grows, more people can get loans, which leads them to buy things that use more energy, like cars, homes, and equipment. This either leads to more energy use or less efficient ENU (Shah et al., 2022). Saud et al. (2018) investigate the influence of FD on ENU, considering globalization from 1980 to 2016 in the context of China. By adopting the ARDL framework, they reveal that financial growth enhances energy consumption. Hussain and Zhou (2022) examine the impact of URB, and FD on ENU in 92 Belt and Road Initiative countries from 1995 to 2018. They used the System GMM and DKSE approach; they demonstrate that financial development significantly elevates energy demand. Ganda (2024) uses the GMM panel VAR framework to look at how expansion in finances affects energy use in the BRICS countries. They observe a substantial positive correlation between FD and ENU. However, Achuo et al. (2025) investigate the impact of financial growth and human capital on ENU across a panel of 134 countries from 1996 to 2019. Using the system GMM method, they found that financial growth greatly reduces the use of fossil fuels while having an encouraging and substantial consequences on overall power usage. In a similar vein the destructive consequences of development in finances on the demand of energy also observed by Alam et al. (2015) and Hao et al. (2024). Farooq and Dar (2024) analyze the influence of financial progress and instability in politics on India's usage of renewable and fossil fuel energy. The nonlinear ARDL approach was employed, and they observe that FD reduces the consumption of both fossil fuels and clean energy. Gómez and Rodríguez (2019) examine the correlation within development in finances and ENU in NAFTA member regions. The FMOLS and DOLS estimators indicate an inverse association within financial development and ENU.

2.3. Political Stability and Energy

Political stability (POS) is conducive to ecosystem sustainability, facilitating the allocation of resources for the coming generations and their efficient utilization (Kirikkaleli and Osmanlı, 2023). A politically secure environment fosters sustained funds in the clean power sector by promoting R&D and infrastructure enhancement (Behera et al., 2024). Moreover, political stability can enhance policy continuity, reduce risks related to investment, and promote regulatory frameworks that support creativity in green technologies (Eweade et al., 2024; Ozkan et al., 2024). Several researchers examined the link within POS and environment (Pata et al., 2022; Guan et al., 2024). Nonetheless, some studies examine the connection from various perspectives and across multiple regions. For example, Li et al. (2025) observed the influence of political stability on the 71 nations included in the BRI from 2000 to 2022. Using the dynamic STIRPAT model, they found that POS had a moderating consequence on the relationship between fiscal policy and green power as well as the relationship between monetary policy and renewable energy development. Chen et al. (2024) use panel data from 20 regions to study the link within POS and ENU. They do this by building an energy resilience framework. The findings suggest that political uncertainty enhances energy resilience, and they remain valid following a number of robustness tests. Al-Tal and Al-Tarawneh (2021) investigate the influence of POS on ENU in the MENA region. The study observes that POS favorably impacted ENU. Moreover, Sekrafi and Sghaier (2018) explored the impact of corruption, and POS on GDP in 13 MENA areas. The researchers discovered that heightened corruption directly impacts GDP growth, the environment and ENU.

2.4. Trade Openness and Energy

Pan et al. (2019) conducted a study in Bangladesh, indicating that TRD affected national ENU through multiple channels, notably "economies of scale," technological implications and manufacturing factors affected by "composite effects." Arif et al. (2017) analyze the influence of RRD on ENU utilizing data from four chosen Asian nations spanning from 1972 to 2011. By employing the PMG estimation, they affirm the positive implication of TRD on ENU. Zheng et al. (2022) investigate the correlation between TRD and biodiversity loss as well as the utilization of green power technologies in China. Their studies revealed that trade liberalization may result in heightened carbon emissions and diminished usage of clean energy innovation. Moreover, Xing et al. (2024) examined the enduring link among sustainable energy technologies, URB, TRD and G7 nations from 1990 to 2020. They propose that TRD increases ENU. Ramaharo and Razanajatovo (2024) employed the ARDL limit test methodology to investigate the macroeconomic determinants affecting Madagascar's green ENU. They indicate that TRD encourages green power usage. Husain et al. (2024) analyzed the implication of TRD on ENU in studies conducted in the G-7 nations from 1990 to 2020. The application of the FMOLS and DOLS methods demonstrates that commerce contributes to an escalation in energy demand. However, throughout time, trade liberalization facilitated access to sophisticated technology that enhances energy utilization, often leading to fall in ENU (Khan et al., 2023). Few researchers shows the favorable consequences of traded liberalization on ENU for example, Ridwan et al. (2024b) examine the intricate interplay among tourism, advances in technology, globalization, and ENU in a prominent tourist areas. With the help of Panel ARDL and Quantile Regression, they demonstrated that TRD has inverse connection with ENU.

2.5. Urbanization and Energy

Urbanization (URB) is greatly correlated with GDP expansion driven by industrialization, which facilitates the transition of rural farming labor to the city service and manufacturing industries (Azam et al. 2015). Consequently, urbanization typically results in increased energy demand, as energy consumption is a normative occurrence (Al-Mulali and Ozturk, 2015). Salim et al. (2019) sought to observe the implication of URB on ENU in specific Asian developing nations. They indicated that URB positively influenced the release of pollutants and ENU. Oteng-Abayie and Mensah (2024) examine the consequence of URB and enhancements in industrial structure on ENU in Sub-Saharan Africa. They looked at data from 36 regions between 1980 and 2019 and demonstrate that URB has an encouraging and substantial connection on energy levels, including the amount of electricity, primary energy, and oil used. Mrabet et al. (2019) analyzed instances from industrialized and emerging nations and observed that URB exerts a favorable influence on non-renewable ENU, with a more pronounced effect than GDP. Moreover, Madlener and Sunak (2011), Franco et al.(2017), and Wang et al. (2022). Moreover, Salim and Shafiei (2014) used the STIRPAT model to look at the relationship within URB and REC from 1980 to 2011. The research revealed a notable positive correlation among population density, urbanization, and NREC. Furthermore, Raghoo et al. (2018) claimed that urbanization is essential in enhancing consciousness and promoting the shift to clean energy sources by fostering a higher inclination to embrace renewable energy technologies.

2.6. Literature Gap

Previous studies have examined individual elements of these correlations separately. Nonetheless, there is a limitation of investigations examining the cumulative effect of these variables on ENU within the context of Bangladesh. There isn't a lot of research that specifically looks at how renewable energy, trade liberalization, political stability, and financial growth affect energy demand in Bangladesh, even though these factors are becoming more and more recognized as important. The existing research frequently focuses on limited elements or unique studies, leading to a significant deficiency in comprehending the influence of political stability, expansion in finances, trade liberalization, and urbanization on sustainable energy demand in this particular regional context. The current research delivers a detailed and broad explanation of the complex correlations within the chosen exogenous variables and energy demand. The goal of this analysis is to fill in a deficiency in the research by shedding light on the specific strategies and connections that either help or hurt the use and adoption of green power resources in this region. This will provide useful information for government officials, investors, and energy-saving projects in Bangladesh.

3. DATA AND METHODOLOGY

3.1. Data and Variables

This study looked at information from the WDI, the IMF, and UNCTAD to see how TRD, GDP expansion, urbanization, political stability, and financial development affected Bangladesh's energy use from 1996 to 2021. This nation and chosen parameters are our first preference for this investigation due to the relevance of their data from the location's standpoint and its accessibility for the present papers requirements. In this instance, we utilize energy demand as an endogenous factor which is obtained from the WDI. The WDI data allows for the estimation of GDP per capita in US dollars for the year 2015. The WDI counterpart also provides data on trade openness (measured as % of GDP) and urbanization. The key policy variables in our research are stability in politics and growth in finance, which we obtained from two distinct sources: UNCTAD and IMF, respectively. Furthermore, the development of finance is quantified using a financial development index, which provides useful conclusions into the implication of progress in finances on energy use. Table 1 provides a concise and easily understood characterization of the variable.

3.2. Theoretical Framework

This research identified multiple independent variables to assess their impact on ENU in Bangladesh Voumik et al.(2023b) claimed that there exit a positive link between GDP, urbanization and ENU. Besides, financial expansion may facilitate consumer financing for individuals, thereby enhancing the acquisition of energy-intensive equipment (Dogan and Seker, 2016; Yang et al., 2021). Moreover, trade can influence energy consumption via several mechanisms, such as changes in traded commodities and services, adjustments in production techniques, and improvements in innovation (Koengkan et al., 2021; Zhou and Li, 2022; Shinwari et al., 2024). These analyses highlight that ENU correlates with GDP, financial development, urbanization, political stability, and urbanization. Our empirical model is:

$$ENU = f(GDP, FD, POS, TRD, URB) \quad (1)$$

Consequently, we have formulated the subsequent fundamental econometric model:

$$ENU_t = \varphi_0 + \beta_1 GDP_t + \beta_2 FD_t + \beta_3 POS_t + \beta_4 TRD_t + \beta_5 URB_t + \mu_t \quad (2)$$

In equation (2) the constant term is denoted by φ_0, and the slope coefficients β_1, β_2, β_3, β_4, β_5 represent GDP growth, FD, POS, TRD and URB. Additionally, t indicates the time period, whereas μ_t signifies the error term, which is consistently considered to have a mean of zero. Moreover, equation (3) represents the logarithmic version of the model:

Table 1: Data and Variables

Variables	Description	Long Form	Unit of measurement	Source
ENU	Energy Demand	LENU	Energy Use (Kg of Oil equivalent per capita)	WDI
GDP	Economic Growth	LGDP	Gross Domestic Product (Current US$)	WDI
FD	Financial Development	LFD	Financial Development Index	IMF
POS	Political Stability	LPOS	Political Stability, Estimates	UNCTAD
URB	Population	LURB	Urban Population (% of total population)	WDI

$$LENU_t = \varphi_0 + \beta_1 LGDP_t + \beta_2 LFD_t + \beta_3 LPOS_t + \beta_4 LTRD_t + \beta_5 LURB_t + \mu_t \quad (3)$$

4. EMPIRICAL STRATEGY

To explore the connection within ENU and things like GDP expansion, POS, URB, FD, and trade liberalization in Bangladesh, the research adopted the ARDL approach to estimate data. Furthermore, we incorporated the FMOLS, DOLS, and CCR approaches to check consistency. Different unit root assessments were performed at the outset of the investigation to ascertain stationarity. Due to the characteristics of the time series data, the ARDL bounds test was subsequently conducted. Additionally, various diagnostic evaluations and Pairwise Granger causality tests were conducted.

4.1. Unit Root Tests

In our investigation, we have adopted the ADF created by Dickey and Fuller (1979), P-P introduced by Phillips and Perron (1988) and DF-GLS test established by Elliott et al. (1992). As a single unit-root test fails to elucidate the identification of distinct regression errors across each cross-section (Anwar et al., 2022; Akther et al., 2025). On the other hand, the P-P test considers serial correlation in the error terms without using lagged difference terms, hence offering a benefit over the DF and ADF test techniques. Moreover, the DF-GLS test has enhanced power in the presence of an uncertain mean or trend, so surpassing all other prevalent unit root tests, including DF, ADF, and PP tests (Luitel and Mahar, 2016).

4.2. ARDL Method

The ongoing correlation within the selected parameters is considered utilizing the ARDL bound (Pesaran et al., 2001) test for cointegration. This approach offers numerous benefits over typical methods regarding the sequence of integration (Raihan et al., 2025). It is relevant when factors are stable at the level or first difference form (Azam et al., 2023). Furthermore, the ARDL method is also useful because it can calculate both the short-term and long-term effects of regressors on the variables (Shahid et al., 2022). Here is the outline of the ARDL bound analysis method.

$$\begin{aligned}\Delta LENU_t = {} & \lambda_0 + \vartheta_1 LENU_{t-1} + \vartheta_2 LGDP_{t-1} + \vartheta_3 LFD_{t-1} \\ & + \vartheta_4 LPOS_{t-1} + \vartheta_5 LTRD_{t-1} + \vartheta_6 LURB_{t-1} \\ & + \sum_{i=1}^{m} \lambda_1 \Delta LENU_{t-1} + \sum_{i=1}^{m} \lambda_2 \Delta LGDP_{t-i} \\ & + \sum_{i=1}^{m} \lambda_3 \Delta LFD_{t-i} + \sum_{i=1}^{m} \lambda_4 \Delta LPOS_{t-i} \\ & + \sum_{i=1}^{m} \lambda_5 \Delta LTRD_{t-i} + \sum_{i=1}^{m} \lambda_6 \Delta LURB_{t-i} + \varepsilon_t \end{aligned} \quad (4)$$

If the F-statistic stays inside the defined upper and lower threshold limits, the null hypothesis can be accepted (Shahid et al., 2024). We employed the notations "H_0" and "H_A" for the null hypothesis and alternative hypothesis, respectively. Equations (5) and (6) display the alternative and null hypotheses:

$$H_0 = \lambda_1 = \lambda_2 = \lambda_3 = \lambda_4 = \lambda_5 = \lambda_6 \quad (5)$$

$$H_A = \lambda_1 \neq \lambda_2 \neq \lambda_3 \neq \lambda_4 \neq \lambda_5 \neq \lambda_6 \quad (6)$$

The "Error Correction Term" is used to evaluate short-term correlations utilizing the ECM to construct long-term associations. We took Equation (7) for the long-term analysis of the ARDL.

$$\begin{aligned}\Delta LENU_t = {} & \lambda_0 + \sum_{i=1}^{m} \lambda_1 \Delta ENU_{t-i} + \sum_{i=1}^{m} \lambda_2 \Delta LGDP_{t-i} \\ & + \sum_{i=1}^{m} \lambda_3 \Delta LFD_{t-i} + \sum_{i=1}^{m} \lambda_4 \Delta LPOS_{t-i} + \sum_{i=1}^{m} \lambda_5 \Delta LTRD_{t-i} \\ & + \sum_{i=1}^{m} \lambda_6 \Delta LURB_{t-i} + ¥ECT_{t-i} + \varepsilon_t \end{aligned} \quad (7)$$

In this case, the sign means the rate of adjustment.

4.3. Robustness Check

The FMOLS (Hansen and Phillips, 1990) estimator does a better job of showing how co-integration works while also dealing with endogeneity and serial correlation issues (Ridwan et al., 2023). It can account possible connections between error terms, constant terms, and changes in regressors (Wang and Ullah, 2024). Moreover, the DOLS test is employed to uncover long-run coefficients, as it addresses small sample bias, autocorrelation, and endogeneity, and is applicable even when factors display varying integrated degrees (Jin et al., 2024). Park (1992) developed the CCR technique, which converts numerical data utilizing only the stationary component of a linked system.

4.4. Pairwise Causality Test

Granger (1969) proposed employing time-series data to determine the causal relationship among economic variables. Granger causality has two primary scenarios: either x must Granger cause y or y must Granger cause x if the two variables, x and y, are co-integrated (Yousefi, 2015). The below equations represent this test.

$$X_t = \partial_1 + \sum_{i=1}^{m} \alpha_i Y_{t-i} + \sum_{i=1}^{m} \mu_i X_{t-i} + e_t \quad (8)$$

$$Y_t = \partial_2 + \sum_{i=1}^{m} \Omega_i Y_{t-1} + \sum_{i=1}^{m} \infty_i X_{t-i} + \mu_t \quad (9)$$

4.5. Diagnostic Tests

Several diagnostic examinations, like the LM test, were used in the study to look for serial correlation. The BPG test is employed to evaluate the existence of heteroscedasticity. Furthermore, we employ the JB test to confirm the normality of the residuals, thereby evaluating the accuracy of the data used for the model's variables. To check how reliable the demonstration is, the CUSUM and the CUSUMSQ tests are used.

Table 2: Summary statistics

Statistic	LENU	LGDP	LFD	LPOS	LTRD	LURB
Mean	5.109872	6.441837	−1.63358	−0.91414	3.435277	3.31106
Median	5.088167	6.184581	−1.60049	−0.9571	3.389758	3.301771
Maximum	5.412497	7.817162	−1.26751	0.148815	3.873509	3.662716
Minimum	4.705389	5.606041	−2.0495	−1.88383	2.983623	2.986237
Standard Deviation	0.259229	0.70473	0.227276	0.523069	0.216181	0.213006
Skewness	−0.07125	0.628733	−0.26638	−0.04487	−0.04658	0.108122
Kurtosis	1.507243	2.095285	1.800173	1.504808	2.289646	1.677159
Jarque−Bera	2.998177	3.199638	2.297883	2.991539	0.684377	2.395561
Probability	0.223334	0.201938	0.316972	0.224076	0.710214	0.301836
Sum	163.5159	206.1388	−52.332	−29.2525	109.9288	105.9593
Sum square deviation	1.983061	15.39597	1.60128	8.481638	2.114683	1.40652
Observations	32	32	32	32	32	32

Table 3: Unit root test

Variables	ADF		P-P		DF-GLS		Decision
	I (0)	I (1)	I (0)	I (1)	I (0)	I (1)	
LENU	−0.987	−5.354***	−0.811	−4.034***	−0.742	−5.012***	I (1)
LGDP	2.503	−3.798***	0.414	−4.059***	1.087	−3.985***	I (1)
LFD	−1.506	−3.996***	−1.610	−4.190***	−0.875	−3.851***	I (1)
LPOS	−3.086**	−6.760***	−3.081**	−5.433***	−2.981**	−4.088***	I (0)
LTRD	−1.977	−4.993***	−0.877	−5.981***	−1.293	−4.062***	I (1)
LURB	−4.321***	−6.313***	−3.989***	−6.928***	−4.208***	−5.813***	I (0)

5. RESULTS AND DISCUSSION

5.1. Descriptive Analysis

The descriptions of the examined elements used in the article are examined in Table 2. This shows that LGDP (6.4418) has the largest mean value, while LFD (−1.6335) has the lowest. Similarly, the LGDP exhibits the highest value (7.8171), while the LFD has the lowest value (−2.0495). Furthermore, all variables have predicted standard deviations below 3, suggesting a concentration of data points around the mean with negligible temporal fluctuation. Most variables, except LGDP and LURB, exhibit a predominance of negative skewness values, suggesting a left-skewed data set. Additionally, kurtosis values below three indicated the presence of platykurtic variables. The JB assessment and the P-values both demonstrated that all factor exhibited a normal distribution. The findings from the study also revealed that no parameter exhibited a substantial variation from its respective mean values.

5.2. Unit Root Assessment

In Table 3, the tests were done on log-transformed data at both levels and first differences. The ADF test indicates that only the LPOS and LURB variables are stationary at level (I(0)) form. Furthermore, the LPOS is significant at the 5%, whereas the LURB is important at the 1% level. Similarly, the analysis of P-P and DF-GLSs revealed analogous results. However, in all instances, the remaining factors, such as GDP expansion, ENU, FD, and TRD, exhibited non-stationary at their (I(0)) but becomes stationarity after (I(1)). Moreover, all these variables are statistically significant at the 1% threshold, after I(1). After running the stationarity test, it was found that the series stays the same at both I(0) and I(1), which means that the ARDL limit test can be used in the research.

5.3. ARDL Bound Test

In Table 4, we can establish a sustained connection within the factors if the projected F-test value exceeds both the upper and lower thresholds. The absolute value of the F-statistic (7.9816) in this case outweighs the maximum critical value level. Therefore, we reject the null hypothesis of no cointegration at 1% level. Conversely, there exists no proof of cointegration between the exogenous parameters and ENU in Bangladesh.

Table 4: ARDL bound test

Model Information	Test Statistics	Value	K	
	F statistics	7.9816	5	
	Significance level			
Critical bounds	10%	5%	2.50%	1%
I (0)	2.17	2.45	2.81	3.08
I (1)	3.12	3.41	3.84	4.19

Table 5: ARDL short-run and long-run results

Variables	LR	SR
LGDP	0.317**(0.0826)	
LFD	−0.192*(0.1982)	
LPOS	0.817**(0.0162)	
LTRD	1.166***(0.0432)	
LURB	1.775**(0.2541)	
D.LGDP		0.116***(0.0776)
D.LFD		−0.481**(0.2123)
D.LPOS		0.556***(0.0741)
D.LTRD		1.815***(0.0814)
D.LURB		1.024**(0.3129)
ECT (Speed Adjustment)		−0.665***(0.0276)
Constant		−4.515***(1.6982)
R-square	0.789	

5.4. ARDL Structure

The ARDL test is employed to determine the coefficients' values for both longer and shorter periods, given the cointegration of the regressors and regressand. Table 5 displays the comprehensive set of results. In the short term, there is a rise in ENU of 0.116 %

Table 6: Robustness check

Variables	FMOLS	DOLS	CCR
LGDP	0.433***(0.0741)	0.308*(0.0212)	0.401**(0.0581)
LFD	−1.254**(0.1733)	−0.598*(0.2987)	−0.744**(0.1102)
LPOS	0.772**(0.0729)	0.371**(0.0541)	0.422***(0.0983)
LTRD	0.914***(0.1027)	0.861***(0.0510)	1.023**(0.0142)
LURB	1.128***(0.2930)	0.877*(0.2791)	0.761***(0.2381)
C	−3.982***(1.0236)	−4.042***(1.2033)	−3.872***(1.6552)

Table 7: Pairwise causality test

Null hypothesis	Obs	F-Statistic	Prob.
LGDP≠LENU	30	2.96333	0.07
LENU≠LGDP	30	2.7024	0.0886
LFD≠LENU	30	1.39706	0.266
LENU≠LFD	30	3.25342	0.0555
LPOS≠LENU	30	5.98044	0.0075
LENU≠LPOS	30	0.00639	0.9936
LTRD≠LENU	30	2.65403	0.0901
LENU≠LTRD	30	0.46444	0.6338
LURB≠LENU	30	1.9384	0.165
LENU≠LURB	30	4.87713	0.0163

for every 1% increase in GDP and the result is significant at 1%. This connection is further amplified, with a 1% spike in GDP resulting in a 0.317% surge in ENU over time and it is significant at 5% level. The findings is corroborated by some scholars such as Ridzuan et al. (2023), and Song et al. (2023). On the contrary, utilization of energy has been a fundamental element of GDP expansion in numerous emerging nations, as it facilitates diverse economic activity (Danish et al., 2020; Nathaniel and Bekun, 2020).

Conversely, in the event of a 1% increment in FD, there is an associated short-term expansion of 0.481% and a long-term fall of 0.192% in energy demand. The result is significant at 10% in the long run and 5% in the short run. An advanced finance structure can alleviate the financial limitations faced by firms, enabling them to modernize manufacturing processes and equipment, thereby significantly enhancing energy efficiency (Kim and Park, 2016). Furthermore, financial growth acts as a catalyst, enhancing the demand for green power (Denisova, 2020). Inversely, multiple investigations like Çoban and Topcu (2013), Danish et al. (2018), and Tinta et al. (2021) concluded that financial development increases more energy consumption.

On the other hand, it can be shown that a 1% intensification in political stability results in a subsequent growth of 0.817% energy demand in overtime and a 0.556% intensification immediately. Several researchers opposed these findings, for example, Ali et al. (2020) in differenregionson. However, Sohail et al. (2022) assert that political instability diminishes clean ENU and unfavorably affects the natural world in the long term. Furthermore, the level administration significantly influences the enhancement of green energy consumption (Uzar, 2020). Additionally, it has been observed that a 1% improvement in the trade liberalization causes to a rise in energy consumption of 1.815% in the near time and 1.166% in the long run. At the same way, Shahbaz et al. (2018), Bashir et al. (2020), and Sadorsky (2011) also demonstrated the unfavorable connection between trade liberalization and energy dmand. Furthermore, Han et al. (2022) demonstrated that trade substantially elevates non-renewable energy usage across all quantiles while only marginally augmenting green energy use. Conversely, Ibrahiem and Hanafy (2021) explored that liberalization in trade has favorable consequences on energy consumption in North African countries.

Similarly, a 1% improvement in LURB leads to an upsurge in LENU by 1.024% immediately and 1.775% over time. Moreover the result is significant at 5% level in both time periods. Bangladesh's swift urbanization undermines the intrinsic nature of financial growth by affecting the creation of businesses, housing, and various forms of infrastructure, all these causes ecological destruction (Zhu and Peng, 2012). Similarly, rising population exerts pressure on natural assets by elevating the demand for housing, transportation, energy usage (Ridwan et al., 2024c; Raihan et al., 2024). In a similar vein, multiple studies like Warsame (2022), Voumik et al. (2023a) and Jia and Wang (2024) found the unfavorable connection between urbanization and energy demand in different region. However, Vacu-Ngqila and Odhiambo (2024) reveal that urbanization causes more energy usage in short run but over time it decreases energy demand in South Africa.

Moreover, the calculated coefficient for ECT is negative and exhibits statistical significance at 1%. It implies that there is an approximate 66.5% rate of annual adjustments made to rectify temporary deviations from long-term equilibrium. The R^2 value is 0.789 which means the regression model well captures the patterns observed in the data.

5.5. Robustness Check

The study examined the estimates of FMOLS, DOLS, and CCR to confirm the conclusion of the ARDL test, as illustrated in Table 6. Firstly, a 1% increment in LGDP of 1% leads to increases in LENU of 0.433%, 0.308%, and 0.401%, respectively. The LFD variable exhibits a negative correlation with LENU, suggesting that enhanced financial improvement may reduce energy demand due to adequate funding for green energy. A 1% increase in LFD will decrease LENU by 1.254%, 0.598%, and 0.744%, respectively. Furthermore, the outcome is significant at 10% in DOLS and 5% in FMOLS and CCR estimations. On the other hand, an extra 1% rise in LPOS raises LENU by 0.772%, 0.371%, and 0.422%, respectively. This shows that political stability raises energy demand during infrastructure development. Correspondingly, the three estimations indicated that a further 1% increase in trade openness will elevate LENU by 0.941%, 0.861%, and 1.023%, respectively. Furthermore, the outcome is significant at 1% in FMOLS and DOLS and at 5% in the CCR estimate. This suggests that trade liberalization intensifies energy demand due

Figure 1: CUSUM and CUSUMSQ test

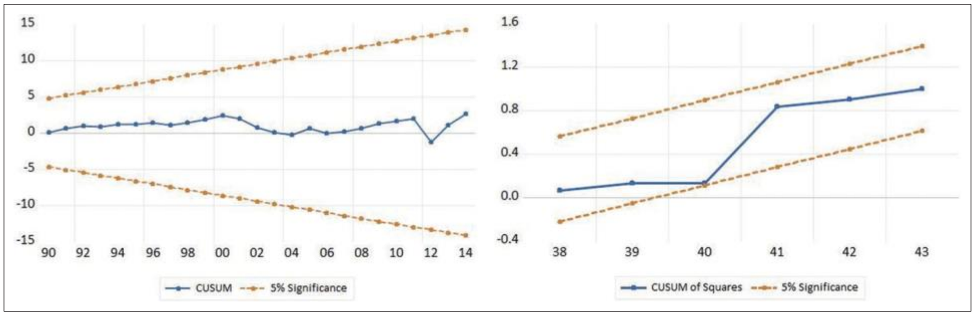

Table 8: Results of diagnostic test

Diagnostic tests	Coefficient	P-value	Decision
Jarque-Bera test	0.49011	0.1032	Residuals are normally distributed
Lagrange Multiplier test	0.60871	0.2011	No serial correlation exits
Breusch-Pagan-Godfrey test	0.49901	0.1092	No heteroscedasticity exists

to logistical and industrial activities in Bangladesh. Different methods, like FMOLS, DOLS, and CCR, exhibit that an extra 1% rise in LURBA will cause LENU to rise by 1.128%, 0.877%, and 0.761%, respectively. Furthermore, the coefficient is significant at the 1% level in FMOLS and CCR and at the 10% level in the DOLS estimate. Overall, the short- and long-term estimation from ARDL are corroborated by tests that show how well they explain how energy use in Bangladesh is linked to different factors.

5.6. Pairwise Causality Test

Table 7 presents the results of the Pairwise Granger Causality study on the causality of the variables. The outcomes indicate an F-statistic of 2.9633 and a P-value of 0.07, suggesting that LGDP Granger-causes LENU. At the 5% significance level, this means we can't reject the null hypothesis that the components don't have any relationship with each other. Conversely, the P-value (0.0075), which is below the usual significance threshold, confirms the one-way causation from LPOS to LENU. Similarly, there is one way causality between LURB and LENU as their associated p value is 0.0163. Consequently, we dismiss the null hypothesis asserting the absence of a causal relationship among these factors. Also, P-values above the usual level of significance for each case show that there isn't a strong causal relationship between LFD, LTRD, LURB, and LENU. These findings suggest that changes in urbanization, financial development, and trade openness do not affect energy consumption in Bangladesh, nor does energy demand affect these factors. Thus, it is not feasible to dismiss the null hypothesis that no causality exists in these interactions.

5.7. Diagnostic Test

Additionally, this research used a number of diagnostic methods to check the accuracy of the ARDL data shown in Table 8. The P-value of 0.1032 in the JB evaluation suggests a normal distribution of the residuals. Second, the Lagrange multiplier test shows that there is no serial correlation in the residuals, which gives a P-value of 0.2011. Finally, the Breusch-Pagan-Godfrey test for heteroscedasticity yields a P-value of 1.092, suggesting that the residuals are homoscedastic.

The study also used the CUSUM and CUSUM-SQ statistics to check how stable residuals are overall over both long and short periods of time. The CUSUM-SQ plot remains on the crucial line, as depicted in Figure 1. This finding indicates that the results are within the required thresholds. This indicates that the parameters are reliable and consistent at the 5% significance range.

6. CONCLUSIONS AND POLICY RECMMENDATIONS

The paper considered the effects of GDP growth, FD, TRD, POS, and URB on ENU in Bangladesh from 1995 to 2021. The stationarity of the data series has been verified adopting the ADF, PP, and DF-GLS unit root testing methodologies. Furthermore, the ARDL bound examination validates the long-term cointegrating relationship among the factors. It identifies that GDP, TRD, POS, and URB as the principal determinants of ENU. In contrast, we determined that only advancements in finance favorably impact ENU in Bangladesh. Additionally, a 1% rise in FD results in a favorable impact on ENU, leading to a reduction of 0.192% in long-term and 0.481% in short-term energy consumption. These results suggest that socio-economic factors should be included in macroeconomic plans along with goals for fair growth and practices that are beneficial for the environment. The conclusions of the ARDL framework were validated by the FMOLS, DOLS, and CCR estimations. Additionally, the Pairwise Granger causality test indicates a unidirectional link among LPOS, LURB, and LENU. Nevertheless, it identified no correlation among GDP growth, FD, TRD, and ENU. Therefore, the study sets up a framework for moral choices by supporting policies for energy conservation, sustainable urban development, and fair growth that encourages Bangladesh to use clean energy and be more energy efficient. This will help the region last and grow in the future.

To ensure sustainable energy management in Bangladesh, policymakers should implement regulatory measures to enhance energy efficiency, promote renewable energy, and develop sustainable trade and urbanization strategies. Given the positive correlation between GDP growth, trade openness, political stability, and urbanization with energy demand, the government should introduce stringent energy conservation policies, incentivize energy-efficient technologies, and promote public awareness campaigns. Expanding investment in renewable energy sources, such as solar and wind power, alongside supportive policies for private sector involvement, will help reduce dependence on fossil fuels. Strengthening financial development through green financing, low-interest loans, and institutional support for sustainable projects can mitigate excessive energy consumption. Additionally, fostering sustainable trade practices by encouraging energy-efficient production and regulatory frameworks will ensure responsible industrial growth. Urbanization should be managed through smart city planning, sustainable transport systems, and energy-efficient infrastructure to minimize energy-intensive activities. By integrating these strategies into national policies, Bangladesh can achieve long-term energy sustainability, balancing economic growth with environmental responsibility. These measures will not only reduce overall energy demand but also support the country's transition toward a more resilient, eco-friendly economy, contributing to global climate commitments and ensuring a sustainable future for future generations.

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