BUFT Journal of Business & Economics (BJBE)
ISSN 2664-9942 (Print)
2025 Volume 6, Pg: 01-18
DOI: https://doi.org/10.58481/BJBE/2501

Dynamic Relationships among Energy Consumption, Gross Capital Formation, Carbon Emissions, and Economic Growth in Bangladesh

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ARTICLE INFO

Article History
Received: May 01, 2025,
Accepted: August 10, 2025

Keywords:
Energy consumption, Carbon emission, GDP, ARDL

JEL Classification:
F4, O2, P2, P3, P4

ABSTRACT

Purpose: This paper aims to examine the dynamic relationship among energy consumption, gross capital formation, carbon emissions, and economic growth in Bangladesh over the period from 1972 to 2022.

Methodology: The study utilizes the autoregressive distributed lag (ARDL) method and Granger causality tests to find out dynamic interrelationships among the study variables.

Findings: The co-integration test implies that in the long-run all the variables are co-integrated. In the long-run, the results reveal that energy consumption and gross capital formation (GCF) have a positive effect on economic growth, while carbon emissions (CO2) have an inverse impact on it. The results of short-run dynamic coefficients of the ARDL model show that CO2 is negatively related to GDP, while GCF has a positive impact on GDP. The pairwise Granger causality implies that there exists unidirectional causality from economic growth to energy consumption. There also exists a unidirectional causality from economic growth to CO2 and a bidirectional causality from GCF to GDP.

Practical Implication: This study offers a suitable environment that would allow us to identify the current policy gaps, and a substantial shift in low-carbon technology, such as energy efficiency and renewable energy, may help reduce emissions and maintain the long-term viability of the economy.

Originality/Value: Earlier research in this field has abandoned the environmental synthesis of the relationship between energy use and economic growth. Using the most recent data set, this study contributes to the small body of literature already available on the nexus among energy consumption, gross capital formation, carbon emissions, and economic growth in Bangladesh.

Limitation: The current study employs a specific country; however, further studies may be conducted using South Asian countries.

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1. Introduction and Background of the Study

The rise in global energy consumption has gained significant attention in the twenty-first century, due to its direct impact on nations' economic growth. However, because of its detrimental impacts on the environment, this rise in energy use has raised concerns around the world and poses a significant threat to sustainability. Therefore, one of the biggest difficulties facing all nations is maintaining economic growth in balance to lessen the effects of global warming. (Akram et al., 2023).

Bangladesh is a South Asian country that is still developing. Bangladesh's economy is growing rapidly, and this trend is expected to continue in the future (Alam et al., 2019). The natural environment has a significant impact on economic events. It makes a direct contribution by supplying resources and raw materials that are needed as inputs for production, such as water, wood, and minerals, as well as indirectly through ecosystem services such as carbon sequestration, water refining, flood risk management, and nutrient cycling. Natural resources are extremely important for assuring economic growth and development, both for today's generation and future generations.

Economic growth and environmental protection have a complicated relationship. Several factors are at play, including the economy's size and composition, mainly the portion of services in GDP as distinct from primary businesses and manufacturing, and technological advancements, which have the prospective to reduce the environmental influences on both production and consumption choices while also motivating economic growth (Saudi et al.,2019). Where globalisation has completely changed the world, numerous concerns have arisen, but energy has gotten a lot of attention from scholars. In our globalising society, the demand for energy is continuously increasing. The majority of countries are experiencing energy shortages, which is having an adverse impact on economic growth. The hunt for alternative and renewable energy sources has now become a necessity for countries. Energy has become a critical function for every country's economic progress, as it enhances the country's efficiency and production. The usage of energy has increased as a result of substantial industrialisation, urbanisation, and population growth, particularly in emerging countries (Ashraf et al., 2020). Both developed and emerging countries rely heavily on energy for economic progress. According to the growth hypothesis, energy consumption is, directly and indirectly, an essential element of growth. It can be used as a supplement to capital and labour as a production input. Energy is a vital element input for both production and consumption activities.

Nowadays, energy is considered one of the most important dynamic forces for economic growth (Alam et al., 2021; Sadekin et al., 2021). A shortage of energy supply can hamper social and economic development and the quality of life. The standard of living can be measured by increased agricultural output and industrial output, adequate shelter, well-organised transportation, and various human services are all examples of improvements in the standard of living, and all of these will necessitate an increase in energy consumption (Dantama et al., 2012). The ultimate goal of any economy is to attain an ideal level of economic growth. During economic growth and development, countries face a variety of challenges. The destruction of the environment and pollution are two of the most significant of these. A major amount of the world's energy needs is covered by fossil fuels, whose supply is quickly depleting.

The carbon dioxide emissions from these sources increase the amount of carbon dioxide in the atmosphere, harming green space and causing irreversible damage to the environment. As a result, extremely dangerous climate changes such as droughts, floods, tornadoes, increasing sea levels, and glacier melting occur. In recent years, climate change and global warming have become important environmental issues for both industrialised and developing countries. Carbon dioxide (CO2) emissions have increased significantly as a result of increased worldwide trade and travel, as well as a rapid surge in economic activities all over the world. Environmental degradation is normally initiated by excessive usage of energy and other natural resources, as well as waste (Bozkurt & Akan, 2014).

There are many studies that have been done about energy consumption and economic growth. Many viewpoints emerged from various studies about energy consumption and economic growth. Some studies reveal that energy consumption is a limiting factor in economic growth. Some studies show that energy has no impact on the rate of growth. Energy usage has a substantial impact on economic growth, according to numerous studies. Some studies, on the other hand, show that economic expansion has a considerable impact on energy usage. In our study, we empirically examine the relationship between energy consumption and economic growth and whether it is unidirectional or bidirectional.

CO2 emissions, economic growth, and energy consumption are some of the burning issues in the current economics literature. Though Bangladesh is an agricultural country, the contribution of agriculture to economic growth is decreasing day by day. At the same time, the contribution of the industrial sector is increasing. Energy resources are key sources of production that can help boost economic growth, particularly in countries that use a lot of energy. On the other hand, industrial activities that consume energy may produce hazardous rubbish and gases, which are detrimental to cleanliness and environmental health. Many studies have been done in different countries covering different periods. Previous findings revealed a wide range of outcomes for various countries, different periods, methodologies, and various variables. Such variations could be attributed to country-specific variables. Therefore, this study examines the dynamic relationship among energy consumption, gross capital formation, carbon emissions, and economic growth in Bangladesh.

The remainder of the paper is structured as follows: In Section 2, a review of previous literature is provided. The methodology of the study is shown in Section 3. The result and discussion are presented in Section 4. The conclusion and policy recommendations are shown in Section 5.

2. Literature Review

There are many scholarly articles regarding energy consumption and economic growth in together developed and developing countries. They use various variables covering different periods. Different outcomes have emerged from those studies.

Alam et al. (2012) use the ARDL approach, Johansen cointegration test, and Granger causality test to investigate the possibility of dynamic causality between energy consumption, electricity consumption, carbon emissions, and economic growth in Bangladesh. The findings show that there is a unidirectional causal relationship between energy consumption and economic growth in both the short and long term, but there is a bidirectional causal relationship between electricity consumption and economic growth in the long term, but no causative relationship in the short term. In the short term, there is a unidirectional causal relationship between energy use and CO2 emissions, but in the long term, there is feedback causality. CO2 Granger contributes to both short-term and long-term economic growth.

Alam et al. (2021) use the Granger causality test, VECM technique, and Johansen cointegration test to investigate how energy consumption and environmental degradation (CO2 emissions) affect economic growth in Bangladesh between 1972 and 2018. According to the study, economic growth (RGDP) is positively and statistically significantly impacted by labour, gross capital formation (GCF), electricity power consumption (EPC), and energy consumption (EC), while it is negatively impacted by environmental degradation (carbon dioxide emissions). According to the causality test, there is a bidirectional causal relationship between GCF and RGDP; GCF and labour; EPC and carbon emission; and a unidirectional causal relationship between EC to GCF, carbon emissions (CO2) to GCF, and carbon emissions to EPC.

Rahman & Khondkar (2020) investigate the degree to which the growth of the SME sector has contributed to the economy and highlight the role performed by the SME Foundation in promoting and sustaining SMEs. According to the study, the growth of the SME sector significantly boosted economic growth by supporting already-existing SMEs, opening up non-traditional opportunities, creating jobs, making the labor force more productive and skilled through training, and raising the caliber of goods and services. Since SMEs make up 80% of all industrial jobs and 25% of Bangladesh's GDP, they have been a major contributor to the country's 6%–8% economic growth rate during the past ten years.

Khondkar (2014) examines the developments and upcoming marketing challenges of solar home systems in Bangladesh. Traditional biomass fuels provide about 65% of the nation's energy requirements. The current solar home system market is very outstanding because rural households, especially those with higher incomes, make up the largest market group. The high initial cost is the main obstacle to the system's expansion. The availability of high-quality accessories and issues with set up, implementation, maintenance, and support after the sale are also present.

Ghosh et al. (2014) investigate the nexus between economic growth, CO2 emissions, and energy consumption for Bangladesh from 1972 to 2011. The results demonstrate that carbon emissions have a negative effect on economic growth, while energy consumption has a positive impact on economic growth.

Rahman et al. (2021) examine the empirical relationship between energy consumption and industrialisation using other macroeconomic factors such as manufacturing, infrastructure, and capital formation in Bangladesh from 1975 to 2018. In this paper, the long-run relationship in this process is asserted using the Johansen co-integration estimation. The bidirectional causation between energy consumption and industrialisation is also demonstrated.

Fernandes and Reddy (2020) conducted a study in newly industrialised countries of Asia, namely, China, Indonesia, India, Thailand, Philippines, and Malaysia, by using data from 1971 to 2018. According to the study, economic growth and energy consumption are co-integrated in the long run in Indonesia, China, and India. VECM is used in this study. The variables of this study are energy consumption and real GDP. Both of the variables are incapable of correcting themselves in the event of any shock in the economy. In the case of Malaysia, the Philippines, and Thailand, co-integration does not exist. The paper shows that there exists a unidirectional causality between GDP and energy consumption.

Khan et al. (2020) analyse the relationship between energy consumption, economic growth, and CO2 emissions in Pakistan by using data from 1965 to 2015. According to the ARDL estimates, CO2 emissions increased with energy consumption as well as economic growth in Pakistan in the short and long term. Musa and Maijam (2020) have conducted a study to see the impact of economic growth and energy consumption on the environmental pollution perspective in Nigeria, covering the time span from 1981 to 2014. The ARDL model is used for achieving the desired objective. The result of the study reveals that energy consumption and economic growth have substantial progressive effects on environmental contamination.

Nguyen and Ngoc (2020) use the ARDL approach with a structural break to see the nexus of energy consumption and economic progress in Vietnam. For this purpose, they use the data of GDP and electricity consumption from 1980-1994 and 1995-2016. The empirical findings demonstrate that energy consumption has a long-term positive effect on Vietnam's economic progress. The causality test supports the feedback hypothesis. There is a breakpoint in 1995, and energy consumption's contribution to economic growth from 1995 to 2016 is lower than it was from 1980 to 1994. Waheeda et al. (2019) survey about economic development, energy use, and carbon emission. Economic growth and energy use have been identified as key sources of carbon emissions in previous research.

Sriyana (2019) shows the dynamic effects of energy consumption on economic growth from an Indonesian perspective. The ARDL model is used to show the effects. The paper covers data from 1990 to 2017. The empirical ARDL model shows that energy use, electric power, and renewable energy consumption have significant effects on economic growth. Latief and Lefen (2019) highlight the power and energy sector of Pakistan. They examine the relationship between FDI in the energy and power sector, energy consumption, and economic growth from 1990 to 2017. Johansen co-integration, as well as the Granger causality test, are used to find the causal relationship. The findings of the study show that a significant bi-directional causal relationship exists.

Khan et al. (2019) conducted a study globally by using a dataset of 193 countries over the 1990–2017 period. They examine the relationships among financial development, economic growth, carbon emissions, and energy consumption. For this purpose, they conduct three-stage least squares regression (3SLS), seemingly unrelated regression, and two-step generalised and system-generalised methods of moment approach. According to the findings of this study, economic growth, financial development, energy consumption, and carbon emissions all have an impact on each other. However, energy consumption stifles economic growth. By using instrumental variable regression, Tariq et al. (2018) conclude that by increasing economic growth, energy consumption also increases. They also show that there is a negative link between energy use and growth in commerce. For this study, they use data from 1981 to 2015 from four developing countries, such as Bangladesh, India, Pakistan, and Sri Lanka.

Elfaki et al. (2018) used time series data of Sudan for the period 1984-2014 and applied the ARDL model; the results support the evidence of co-integration of the variables. However, the study's concluding remark is different in that energy consumption has a negative impact on GDP. The aim of Twerefoul et al. (2018) is to investigate the causal link between energy consumption and economic growth from the West African sub-region perspective. The findings show that electricity and petroleum consumption have a positive effect on economic growth.

Using the ARDL technique, Can and Korkmaz (2018) have conducted a study about the linkage between economic growth and renewable energy consumption. The paper covers the data from 1990 to 2016 in Bulgaria. This research yields different outcomes. They reveal that renewable energy consumption is initiated by renewable electricity output and economic growth. Based on the time-series data from 1971-2017, Pandey and Rastogi (2018) conclude that there exists a short-run causality from electricity consumption to economic growth and carbon emissions.

Tursoy and Ercantam (2017) have conducted a study in Belgium. The findings demonstrated a unidirectional relationship between GDP and EC, supporting the conservation hypothesis' validity in Belgium. By applying linear and threshold co-integration tests. Sek, S. K. (2017) demonstrates that it is energy consumption that has a positive impact on GDP. Chowdhury et al. (2017), with the use of the ARDL model, conclude that energy use and economic growth promote each other in both the short and the long run. For this purpose, they used the data from 1979-2014 in Bangladesh.

According to Akhtar et al. (2017), a bidirectional causality exists between energy(gas) use and GDP. This study covers the data from 1976 to 2015 in Bangladesh. Toda and Yamamoto's (1995) Granger causality test is used to conduct the study. By using data from 1985 to 2013, Wahid et al. (2017) conducted a study about economic growth, power consumption, and CO2 emission in Bangladesh. The findings show that in the long run, there is a considerable relationship between economic growth and power use, as well as between economic growth and fossil fuel energy consumption.

By using panel causality, Jamel and Derbali (2016) examine the causal link between environmental pollution and economic aggregates covering the time span 1991-2013 of eight Asian countries. VECM indicates that bidirectional causal links exist between economic growth, energy consumption, and environmental degradation. Husain (2016) uses ARDL to see the long-run relationship between economic growth, energy consumption, and carbon emission in Bangladesh. According to his study, a long-run relationship exists between the variables. Cheng Lu (2016), using panel co-integration, reveals that a 1% increase in power consumption improves real GDP by 1.72 per cent. This study covers 17 Taiwanese industries, covering the data from 1998 to 2014.

Sarker et al. (2016) use VECM covering the time span 1978-2010 to investigate the relationship among FDI, energy consumption, GDP, and natural gas in Bangladesh. The analysis confirms that long-run causality exists in natural gas consumption, industrial energy consumption, and GDP, along with CO2 emissions and FDI. Causal correlations between variables have also been discovered in the short run. By covering the period 1981-2011, Aremu (2014) demonstrates a long-term relationship present in economic growth, energy consumption, and environmental degradation. Granger causality implies a bidirectional causality between economic growth and energy consumption and a unidirectional causality between energy use and CO2.

Safdar and Farooq (2012) have conducted a study based on annual data from 1972 to 2012. This study looks into the link between economic growth and energy consumption in Pakistan. In today's globalising world, the energy demand is continuously rising. Energy scarcity is impacting economic growth in the majority of countries. In Pakistan, the energy sector has received insufficient investment, resulting in the underdevelopment of the majority of commercial energy infrastructure. The demand and supply sides both have faults, particularly when it comes to payments. As a result, a large sum of money is distributed throughout Pakistan due to the cyclical deficit. According to the empirical findings, consumption of electricity, as compared to alternative forms of energy, greatly stimulates economic growth. Because of the large number of imports, oil consumption has a negative impact on economic growth. Trade openness is also a beneficial factor for economic growth in the United States.

By using ARDL, Hossain and Hasanuzzaman (2011) conducted a study about the impact of energy consumption, financial development, urbanisation, and trade openness on the environment in Bangladesh. The study has discovered that carbon emission reduces with the increase in GDP per capita. Belke et al. (2010) use the Error Connection Mechanism(ECM) to examine the relationship between economic growth and energy consumption for 25 OECD countries covering the data from 1981- 2007. The results of the study suggest that price-inelastic behaviour is present in energy consumption, and bi-directional causality is present between the variables.

These assessments indicate that there is a close nexus between energy consumption, gross capital formation, carbon emissions, and economic growth. The influence of those variable factors and policies on several aspects of economic growth in Bangladesh has not been studied. This study may contribute to the literature on economic growth.

3. Methodology of the Study

3.1 Data Sources

This study uses secondary data and employs an annual time series for Bangladesh covering the period from 1972 to 2022. The variables incorporated are GDP per capita, which is used as a proxy for economic growth, energy consumption (EC), carbon dioxide emissions (CO2) is used as a proxy for environmental degradation, and Gross capital formation (GCF). GDP per capita is calculated using constant 2015 US dollars, energy consumption is calculated using energy use (kg of oil equivalent per capita), carbon emissions are calculated using metric tons per capita, as well as gross capital formation is calculated using constant 2015 US dollars. All the data are obtained from the World Bank (WDI). To eliminate heteroscedasticity, all variables are changed to their natural logarithms.

Table 1. *Description and sources of data*

Variables	Description	Source
GDP	GDP per capita (constant 2015 US$)	World Development Indicator
EC	Energy use (kg of oil equivalent per capita)	World Development Indicator
CO2	CO2 emissions (metric tons per capita)	World Development Indicator
GCF	Gross capital formation (constant 2015 US$)	World Development Indicator

Source: Author’s calculation

3.2 Model Specification

The ARDL bounds test is utilised in this study to look at the long and short-term relationship between energy use and economic growth. The ARDL technique of co-integration has a number of advantages over other co-integration methods. Unlike other co-integration procedures, the ARDL bounds test approach can be employed whether the underlying independent variables are integrated of order one I (1) or order zero I (0). Second, ARDL can be used with a small sample size. Third, the ARDL yields unbiased long-run model estimates and reliable t-statistics.

This study uses a log-linear model.

$$ln\,GDP_t = \beta_0 + \beta_1 lnEC_t + \beta_2 lnCO_{2t} + \beta_3 \ln GCF_t + u_t \qquad (1)$$

Where,

GDP = Gross Domestic Product
EC = Energy Consumption
CO2 = Carbon emissions
GCF = Gross Capital Formation
U_t = White noise error term
t = time period
ln = natural logarithm

The following equations offer an unrestricted error correction representation of the ARDL model for the log-linear model:

$$\begin{aligned}\Delta lnGDP_t = \beta_0 &+ \sum_{i=1}^{q1} \beta_{1i}\,\Delta lnGDP_{t-i} + \sum_{i=1}^{q_2} \beta_{2i}\Delta lnEC_{t-i} + \sum_{i=1}^{q_3} \beta_{3i}\Delta lnCO2_{t-i}\\ &+ \sum_{i=1}^{q_4} \beta_{4i}\Delta lnGCF_{t-i} + \delta_0 lnGDP_{t-i} + \delta_1\, lnEC_{t-i} + \delta_2 lnCO2_{t-i}\\ &+ \delta_3 lnGCF_{t-i} + u_t\end{aligned}$$

$$\begin{aligned}\Delta lnEC_t = \beta_0 &+ \sum_{i=1}^{q1} \beta_{1i}\,\Delta lnEC_{t-i} + \sum_{i=1}^{q_2} \beta_{2i}\Delta lnGDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i}\Delta lnCO2_{t-i}\\ &+ \sum_{i=1}^{q_4} \beta_{4i}\Delta lnGCF_{t-i} + \delta_0 lnEC_{t-i} + \delta_1\, lnGDP_{t-i} + \delta_2 lnCO2_{t-i}\\ &+ \delta_3 lnGCF_{t-i} + u_t\end{aligned}$$

$$\begin{aligned}\Delta lnCO2_t = \beta_0 &+ \sum_{i=1}^{q1} \beta_{1i}\,\Delta lnCO2_{t-i} + \sum_{i=1}^{q_2} \beta_{2i}\Delta lnGDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i}\Delta lnEC_{t-i}\\ &+ \sum_{i=1}^{q_4} \beta_{4i}\Delta lnGCF_{t-i} + \delta_0 lnCO2_{t-i} + \delta_1\, lnGDP_{t-i} + \delta_2 lnEC_{t-i}\\ &+ \delta_3 lnGCF_{t-i} + u_t\end{aligned}$$

$$\begin{aligned}\Delta lnGCF_t = \beta_0 &+ \sum_{i=1}^{q1} \beta_{1i}\,\Delta lnGCF_{t-i} + \sum_{i=1}^{q_2} \beta_{2i}\Delta lnGDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i}\Delta lnEC_{t-i}\\ &+ \sum_{i=1}^{q_4} \beta_{4i}\Delta lnCO2_{t-i} + \delta_0 lnGCF_{t-i} + \delta_1\, lnGDP_{t-i} + \delta_2 lnEC_{t-i}\\ &+ \delta_3 lnCO2_{t-i} + u_t\end{aligned}$$

The first difference operator Δ is indicated in the above equations of the bound testing approach. And is the residual term. The existence of a long-run relation is examined by using the F test, where the null and alternative hypothesis is stated:

Null hypothesis, : $H_0{:}\delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$, proposing no co-integration

Alternative hypothesis, : $H_1{:}\delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq 0$, proposing the existence of co-integration

In the bound testing approach, co-integration is based on the F-value outcomes. If the estimated F-value exceeds the upper bound, the null hypothesis is rejected, which means no integration. When the F-value sits between the upper and the lower bound values, however, the result is regarded as undecidable. If the F-value is below the lower bound, then we accept the null hypothesis, and only the short-run relation can be estimated.

The following is the error correction model that is used for estimating short-run relationships:

$$\Delta GDP_t = \beta_0 + \sum_{i=1}^{q1} \beta_{1i}\, \Delta GDP_{t-i} + \sum_{i=1}^{q_2} \beta_{2i} \Delta EC_{t-i} + \sum_{i=1}^{q_3} \beta_{3i} \Delta CO2 + \sum_{i=1}^{q_4} \beta_{4i} \Delta GCF + \eta_1 ECT_{t-i} + u_t$$

$$\Delta EC_t = \beta_0 + \sum_{i=1}^{q1} \beta_{1i}\, \Delta EC_{t-i} + \sum_{i=1}^{q_2} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i} \Delta CO2_{t-i} + \sum_{i=1}^{q_4} \beta_{4i} \Delta GCF_{t-i} + \eta_2 ECT_{t-i} + u_t$$

$$\Delta CO2_t = \beta_0 + \sum_{i=1}^{q1} \beta_{1i}\, \Delta CO2_{t-i} + \sum_{i=1}^{q_2} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i} \Delta EC_{t-i} + \sum_{i=1}^{q_4} \beta_{4i} \Delta GCF_{t-i} + \eta_3 ECT_{t-i} + u_t$$

$$\Delta GCF_t = \beta_0 + \sum_{i=1}^{q1} \beta_{1i}\, \Delta GCF_{t-i} + \sum_{i=1}^{q_2} \beta_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{q_3} \beta_{3i} \Delta EC_{t-i} + \sum_{i=1}^{q_4} \beta_{4i} \Delta CO2_{t-i} + \eta_4 ECT_{t-i} + u_t$$

In the equations to indicates the speed of adjustment, is the lagged error correction term. is expected to be a negative sign and statistically significant.

3.3 Instrument

Now we will discuss what kind of test will be utilised to check for co-integration between energy utilisation and economic progress in this section. We can simply assess if there is any co-integration between the variables using ARDL Bound testing because we use the autoregressive distributed lag strategy to create the model outlined above. The bound test will help us determine if co-integration is short-run, long-run, or non-existent. We can't conduct the test directly since we don't know if the data is stationary or not. To begin, each variable is examined for the presence of a unit root test.

4. Results and Discussion

The results of the empirical study are presented in the preceding chapter, which attempts to determine if there is a causal link between economic growth and energy consumption, as well as other variables included in the model set.

4.1 Descriptive Statistics

The information in Table 2 shows the descriptive statistics of the variables of the study. Firstly, all the variables are transformed into their log value. Mean, median, and standard deviation of per capita GDP are found to be 2.82, 2.76, and 0.18, respectively, with the smallest value of 2.60 and an extreme value of 3.21. Similar statistics for Energy Consumption are found to be 2.16, 2.13, and 2.55, respectively, with a minimum value of 1.94 and a maximum value of 2.55.

Table 2. *Descriptive Statistics*

	ln GDP	ln EC	ln CO2	ln GCF
Mean	2.820	2.162	-0.764	10.047
Median	2.763	2.137	-0.823	10.070
Maximum	3.211	2.551	-0.226	10.917
Minimum	2.604	1.938	-1.278	8.597
Std. deviation	0.178	0.160	0.287	0.566

Source: Author's calculation

The table also shows the descriptive statistics of two variables, namely Carbon Emissions with a measure of metric tons per capita and Gross Capital Formation, which is measured by constant 2015 US dollars. The mean, median, and standard deviation of Carbon Emissions are -0.76, -0.82, and 0.29, respectively, with a minimum value of -1.28 and supreme value of -0.23. The mean, median, and standard deviation of other variables, namely Gross Capital Formation, are 10.05, 10.07, and 0.57 respectively, with a minimum value of 8.60 and a maximum value of 10.92.

4.2 Unit Root Test

Empirical data-driven research presupposes that the underlying time series is stationary. 'A time series is considered to be stationary if its mean, variance, and autocovariance do not change regardless of when we measure it' (Gujarati, 1995). The presence of stationarity indicates that basic statistical characteristics are unaffected by time. The empirical analysis can be carried out using a variety of econometric approaches. The Augmented Dicky-Fuller Unit Root Test is one of the most extensively used statistical methods for determining the stationarity of time series data. The hypothesis to be tested is;

Null hypothesis (H_0): The series has a unit root that is Non-stationary

Alternative Hypothesis (H_1): The series has no unit root that is stationary

Decision criteria: If the test statistic is greater than the critical value, the null hypothesis will be rejected.

Table 3. *Results of Augmented Dickey-Fuller Unit Root Test*

Variables	ADF at Level		Remarks	ADF at First difference		Remarks
	Intercept	Trend and Intercept		Intercept	Trend and Intercept	
LNGDP	3.580**	-4.945*	Stationary	-9.508*	-13.029*	Stationary
LNEC	3.306	1.366	Non Stationary	-6.373*	-7.751*	Stationary
LNC02	-3.117	-3.040	Non Stationary	-35.649*	-34.930*	Stationary
LNGCF	-2.253	-3.096	Non Stationary	-10.361*	-11.163*	Stationary

Note. 1, 5, and 10% levels are indicated respectively by *, **, and ***

Source: Author's calculation

The results of the Augmented Dicky-Fuller unit root test on the variables at their level and first difference value are shown in Table 3. The value of GDP is 3.580, which is significant at a 5% critical level both in the trend and intercept the value. The rest of the variables (LNEC, LNC02, LNGCF) are non-stationary at their level form but stationary at first difference. If we notice, the critical value of GDP is -9.508 in trend and -13.029 in trend and intercept at 1% critical level. Similarly, the critical values of energy consumption are -6.373 and -7.751, respectively. Similarly, another two variables, namely, carbon emissions and gross capital formation, are stationary at their first difference value with a critical level of 1%. However, when the variables are differenced in first order, i.e., I(1), the series is found to be stationary. This means that the Null Hypothesis (H_0) is rejected at their initial differences in the ADF test.

4.3 The ARDL Bound Testing Approach for Co-integration

To determine the long-run relationship between series with different integration orders, the ARDL co-integration technique is applied. After determining the order of integration of the variables, a bound F-test will be applied to establish a long-run relationship among the variables. The hypothesis to be tested is:

Null hypothesis (H_0): $\delta_0 = \delta_1 = \delta_2 = \delta_3 = 0$; proposing no co-integration.

Alternative Hypothesis (H_1): $\delta_0 \neq \delta_1 \neq \delta_2 \neq \delta_3 \neq 0$, proposing the existence of co-integration.

Decision criteria: Based on the value of the F-statistic, we can conclude the following decision:

- The null hypothesis is rejected if the computed F-value outstrips the upper bound, indicating that co-integration occurs and the long-term relationship can be inferred.
- We can't reject the null hypothesis if the F-value is smaller than the lower bound; thus, we can only estimate the short-term connection.
- The result is regarded as undecidable if the F-value falls between the upper and lower bound values.

Table 4. *ARDL bounds test for the existence of Co-Integration*

Dependent variables	Functions	F-Statistics	Outcomes
LNGDP	FGDP (GDP|EC,CO2,GCF) (1,0,1,1)	6.439	Co-integrated
LNEC	FEC (EC|GDP,CO2,GCF) (1,0,0,0)	22.300	Co-integrated
LNCO2	FCO2 (CO2|GDP,EC,GCF) (1,2,1,0)	9.601	Co-integrated
LNGCF	FGCF (GCF|GDP,EC,CO2) (1,2,2,2)	49.255	Co-integrated
Critical Bound Values	1%	5%	10%
Lower Bound I(0)	4.29	3.23	2.72
Upper Bound I(1)	5.61	4.35	3.77

Source: Author's calculation

Table 4 summarises the results of the limits test for co-integration as well as critical values. By setting the maximum lag length to 2, the ARDL model is estimated. When the independent variables are energy consumption, carbon emissions, and gross capital accumulation, and the dependent variable is real GDP per capita; co-integration exists because the calculated F_{GDP} (GDP|EC, CO2, GCF) is 6.439, which is greater than the upper limit critical value at 1%, 5% and 10% significance level. When energy consumption is put as the dependent variable and the remaining three variables namely, real GDP per capita, carbon emissions and gross capital formation are independent variables, the computed F_{EC} (EC|GDP, CO2, GCF) is 22.30, is greater than the upper bound critical value at 1%, 5% and 10% significance level. Similarly, the bounds test indicates that when the carbon emissions and gross capital formation are dependent variables the computed F_{CO2} (CO2|GDP, EC, GCF) and F_{GCF} (GCF|GDP, EC, CO2) are 9.601and 49.255 respectively, which is larger than the upper limit critical value at 1%, 5% and 10% significance level. In all of the cases, co-integration exists, and a long-run relationship is present in the four cases. Hence, the null hypothesis is rejected at 1%, 5% and 10% levels of significance.

4.4 Long-run Coefficients Estimation

The long-run coefficients are estimated using the associated ARDL after determining the presence of long-run equilibrium with real GDP per capita as the dependent variable. Table 5 demonstrates the outcomes of the long-run coefficients of the ARDL model.

Table 5. *Long Run ARDL Results*

Variable	Coefficient	Std. Error	t-Statistic	Probability
LNEC	0.390	0.151	2.583	0.014
LNCO2	-0.284	0.134	-2.12	0.040
LNGCF	0.084	0.017	4.94	0.010

Note. Results of Estimated Long run Coefficients based on ARDL (1,0,1,1).

Source: Author's calculation

There is a long-term positive correlation between energy consumption and economic growth. This suggests that a 1% increase in energy consumption will result in *a* 0.39% increase in economic growth. That means the increase in energy use leads to an increase in economic progress, which is statistically significant at a 5% significance level. This result is consistent with those of Alam et al. (2021), Bozkurt & Akan (2014), Ghosh et al. (2014), and Sadekin et al. (2021).

The relationship between carbon emissions and GDP per capita is negative, which is clear from the negative sign of the coefficient of carbon emissions. That means 1% increase in carbon emissions leads to a 0.28 % decrease in GDP, and it is statistically significant at 5%. Because developing countries use nonrenewable energy resources for industrial and other economic operations, which leads to increased CO2 emissions in the country, their economic activities degrade the environment. This result aligns with the findings of Alam et al. (2021), Bozkurt & Akan (2014), Ghosh et al. (2014), and Sadekin et al. (2021).

Gross capital formation has a significant positive impact on economic growth in Bangladesh. Gross capital accumulation increases by 1%, resulting in a 0.08 per cent increase in GDP, which is considerable at a 5% significance level. The finding is supported by Alam et al. (2021), Alam & Bhowmik (2020), Chowdhury & Alam (2023), and Sadekin et al. (2021).

4.5 Short-run Coefficients Estimation

The results of short-run dynamic coefficients of the ARDL model are shown in Table 6. The model is based on ARDL (1,0,1,1). The sign of the coefficients is the same as long-term coefficients. But the difference is that there is no relationship between energy utilisation and GDP in the short run. The coefficient of carbon emissions is negative, which means carbon emissions and GDP have a negative relationship in the short run. The coefficient indicates that a 1% increase in CO2 leads to a 0.21% percent decrease in GDP, which is slightly smaller than the long-run coefficient and statistically significant.

There is an affirmative linkage between GCF and GDP in the short run. A 1% increase in gross capital accumulation leads to a 0.27% increase in GDP, which is small in proportion but statistically significant.

Table 6. *Short Run ARDL Results*

Variable	Coefficient	Std. Error	t-Statistic	Probability
D (LNEC)	-	-	-	-
D (LNCO2)	-0.214	0.086	-2.488	0.017
D (LNGCF)	0.270	0.091	2.967	0.002
ECT(-1)	-0.548	0.119	-4.605	0.000

Note. Results of Estimated Short Run Coefficients: (1,0,1,1).

Source: Author's calculation

The ECT value validates the integrity of the long-run connection because the error correction term is negative and statistically significant at the 5% level. When there is disequilibrium in the system, the ECT coefficient suggests that it can be adjusted back to long-run equilibrium at a rate of 0.55 per cent. The existence of a long-run link between the variables and their ability to adjust from a state of disequilibrium is demonstrated by the considerably lagged error correction term.

4.6. Diagnostic Tests of the Selected ARDL Model

4.6.1 Serial correlation and Heteroskedasticity test

In time series investigations, serial correlation occurs when errors from one time period transfer over to subsequent time periods. We expect no serial correlation in the model. The hypothesis to be tested is:

Null hypothesis (H_0): No serial correlation

Alternative Hypothesis (H_1): Positive serial correlation

Normally, we want to accept the alternative hypothesis. But this is different from the others. The reason is that we try to accept the null hypothesis in this case.

Table 7 shows the result of the serial correlation and heteroskedasticity test. The Breusch-Godfrey serial correlation LM test is applied in this case. The result of the Breusch-Godfrey serial correlation LM test is 0.0746, which is higher than 5%. This value accepts the null hypothesis, implying that our data is free of serial correlation issues. When we set energy consumption as a dependent variable, the LM result is 0.9111, which is also higher than 5%. Table 7 also shows the heteroscedasticity result of the model. The term "heteroskedastic" describes a situation in which the variance of the residual term or error term in a regression model changes greatly. For testing the heteroscedasticity, Autoregressive Conditional Heteroskedasticity (ARCH) is applied.

Table 7. *Serial correlation and Heteroskedasticity test*

R-square	Breusch-Godfrey serial correlation LM	Heteroskedasticity test: ARCH
Dependent variable – GDP R2 : 0.631 Adj. R2: 0.606	4.050 (0.075)	1.79 (0.181)
Dependent variable – EC R2: 0.106 Adj. R2:0.046	0.012 (0.911)	0.81 (0.369)

Source: Author's calculation

The result of the ARCH is 0.181, which is higher than 5%. So we can say that there is no Heteroskedasticity problem in our data. The result is also true when we set energy consumption as the dependent variable. The value, in this case, is 0.369, which is higher than 5%. The table also shows the result of R^2 and adjusted R^2. R-squared is a statistical measure that measures the proportion of variation explained by an independent variable or variables in a regression model for a dependent variable. Here, the R^2 value is 0.631, which indicates that the 63% variation of GDP per capita can be explained by the independent variables of the model, namely energy utilisation, carbon emissions, and gross capital formation.

4.7 Pairwise Granger Causality Test

There are some prerequisites to testing the causality, such as:

1. The series must be stationary.
2. Sensitive to the number of lagged terms included in the model.
3. Error terms entering the causality test are uncorrelated.
4. Evidence of co-integration (for long-run relationships).

Although co-integration demonstrates the presence of Granger Causality in at least one direction, it does not identify the causality direction between variables. However, our model has passed the above four prerequisites. So our model is ready to test the causality. There are many methods to test the causality. For them, we choose the pairwise Granger causality test.

The study distinguished three cases;

1. Unidirectional causality from one variable to the other.
2. The variables have bidirectional causality.
3. The variables' causality is independent (neutrality).

Table 8. *Pairwise Granger Causality Test*

	Dependent Variables: GDP		**Dependent Variables: EC**		
Variables	Chi-sq	Prob.	Variables	Chi-sq	Prob.
EC	9.8763	0.079	GDP	13.196	0.022
CO2	8.5316	0.129	CO2	23.245	0.000
GCF	20.618	0.001	GCF	9.605	0.087
All	46.877	0.000	All	49.972	0.000
	Dependent Variables: CO2		**Dependent Variables: GCF**		
Variables	Chi-sq	Prob.	Variables	Chi-sq	Prob.
GDP	17.616	0.003	GDP	16.24	0.006
EC	16.359	0.006	EC	4.7959	0.441
GCF	5.724	0.334	CO2	6.5204	0.259
All	44.811	0.000	All	37.64	0.001

Source: Author's calculation

(1) H_0: EC doesn't Granger-cause GDP

H_1: GDP doesn't Granger-cause EC

Table 8. shows that when the GDP is a dependent variable and the energy consumption is an independent variable, the P value is 0.079, which is higher than 0.05. So we cannot reject the null hypothesis, which means EC doesn't Granger-cause GDP. Meanwhile, when energy utilisation is the dependent variable and the GDP is the explanatory variable, the P value is 0.022, which is less than 0.5.

As a result, the null hypothesis is rejected, and the alternative hypothesis that GDP growth causes EC is accepted. This is called unidirectional causality.

(2) H_0: CO2 doesn't Granger cause GDP

H_1: GDP doesn't Granger-cause CO2

When the GDP is the dependent variable and the carbon emissions are the explanatory variable, the P value is 0.129, which is higher than 0.5. As a result, we can't rule out the null hypothesis, which means CO2 doesn't Granger-cause GDP. On the other hand, when we set carbon emissions as the dependent variable and GDP as the explanatory variable, the P value is 0.003, which is less than 0.5. Therefore, we accept the alternative hypothesis that GDP Granger causes CO2. There is a one-way causation between GDP and carbon emissions.

(3) H_0: GCF doesn't Granger cause GDP

H_1: GDP doesn't Granger-cause GCF

When the GDP is the dependent variable and the gross capital formation is an independent variable, the P value is 0.001, which is lower than 0.05. We can therefore ignore the null hypothesis and adopt the alternative hypothesis, which is that GCF Granger causes GDP. Another case is when the GCF is the dependent variable and GDP is the independent variable. In this case, the P value is 0.006, which is less than 0.5, hence rejection of the null hypothesis and acceptance of the alternative hypothesis that GDP Granger causes GCF. Therefore, gross capital accumulation has a substantial effect on economic progression, and economic growth also has a significant effect on gross capital accumulation. Here exists bidirectional causality between the variables.

5. Conclusion and Recommendation

The main goal of this study is to empirically investigate the dynamic relationship among energy consumption, gross capital formation, carbon emissions, and economic growth in Bangladesh from 1972 to 2022. The study applies the ARDL model and Granger causality tests to estimate the causal connection between variables. Before applying the model, it is necessary to know whether the time series is stationary or not. For this reason, an augmented dicky fuller test has been done. The outcomes of the ADF test show that there are mixed results, thus allowing the ARDL test. The co-integration test implies that all the variables are co-integrated in the long run.

The long-run coefficients that are calculated by using the associated ARDL after determining the presence of long-run equilibrium with real GDP per capita are the dependent variable. The findings reveal that in the long run, energy consumption and gross capital formation have a positive effect on real GDP, while carbon emissions (CO2) have an inverse impact on it. The results of the short-run dynamic coefficients of the ARDL model show that the coefficient of carbon emissions is negative, which means carbon emissions and GDP have an inverse connection in the short run. However, there is a positive association between GCF and GDP in the short run. The ECT value validates the integrity of the long-run connection because the error correction term is inverse and significant at the 5% level. When there is disequilibrium in the system, the ECT coefficient suggests that it is adjusted back to long-run equilibrium at a rate of 0.55 per cent.

A pairwise Granger causality test has been applied to examine the causal relationship between variables. Though our main focus is on identifying the causal relationship between energy consumption and economic growth, we have also examined the causal relationship between carbon emissions and economic growth and another pair, that is, gross capital formation and economic growth. The causality result confirms that there is a unidirectional causality from GDP to energy consumption, which is called reverse causality. But energy consumption (EC) does not Granger-cause GDP. And there exists a unidirectional causality between economic growth and carbon emissions. Further, there is a bidirectional causality between gross capital formation and economic growth. That means gross capital formation has a significant effect on economic growth, and economic growth also has a significant effect on gross capital formation. Therefore, the study concludes that there is a dynamic relationship among energy consumption, gross capital formation, carbon emissions, and economic growth in Bangladesh.

Based on the findings, the study provides some important policy recommendations. First, as energy consumption has a significant positive effect on economic growth in Bangladesh, the government should focus on expanding and improving affordable and reliable energy access to stimulate sustainable economic growth. Second, by using energy, carbon dioxide is also emitted that causing environmental degradation. Environmental degradation hampers the total ecosystem. So we should be aware of energy usage. Bangladesh has many gas mines, but the gas should be used properly. Though the Bangladesh government has taken steps to reduce carbon emissions, the emissions are increasing day by day. An alternative way to reduce carbon emissions should have been identified. The industrial sector should use environmentally friendly technology. Overall, public awareness is necessary to reduce carbon emissions. The government should place a greater emphasis on renewable energy consumption to reduce the negative effects of economic activity and fossil fuel energy consumption on the country's environment. Finally, since gross capital formation (GCF) has a positive effect on real GDP in Bangladesh, the government should prioritise policies that stimulate investment in productive assets like infrastructure, machinery, and technology.

References

Aktar, A., Kundu, N., & Khan, M. Z. S. (2017). Testing Causality between Energy Consumption, Carbon Dioxide Emission and Economic Growth in Bangladesh. *SEU Journal of Science and Engineering*, 11(2), 23-35.

Akram, H., Li, J., Anser, M. K., Irfan, M., & Watto, W. A. (2023). RETRACTED ARTICLE: Assessing the impact of human capital, renewable energy, population growth, economic growth, and climate change policies on achieving the sustainable development goals. *Environmental Science and Pollution Research*, *30*(56), 119285-119296.

Alam, M. J., Begum, I. A., Buysse, J., & Van Huylenbroeck, G. (2012). Energy consumption, carbon emissions and economic growth nexus in Bangladesh: Cointegration and dynamic causality analysis. *Energy Policy*, *45*, 217-225.

Alam, M. M., & Bhowmik, D. (2020). The causal relationship among export, imports, capital formation and economic growth in Bangladesh. *Journal of Humanities and Social Science*, 2279-0837.

Alam, M. M., Hassan, M. G., & Sadekin, M. N. (2021). Impact of energy consumption and environmental degradation on economic growth in Bangladesh. *Central Asia and the Caucasus*, *22*(5), 612-628.

Alam, M. M., Muzib, M. M., & Bhowmik, D. (2019). The Comparison of Economic Output between Democracy Period and Military Period in Bangladesh. IOSR Journal of Humanities and Social Science (IOSR-JHSS), 24(5), 20–31. https://doi.org/10.9790/0837-2405032031

Ashraf, M. W., ur Rehman, H., & Chaudhry, I. S. (2020). The Impact of Economic Growth, Foreign Direct Investment, Urbanization, Fossils Fuel Consumption on Environmental Degradation in Emerging Asian Economies. *Journal of Business and Social Review in Emerging Economies*, *6*(4), 1479-1495.

Belke, A., Dobnik, F., & Dreger, C. (2011). Energy consumption and economic growth: New insights into the cointegration relationship. *Energy Economics*, *33*(5), 782-789.

Bhattacharya, M., Paramati, S. R., Ozturk, I., & Bhattacharya, S. (2016). The effect of renewable energy consumption on economic growth: Evidence from the top 38 countries. *Applied Energy*, *162*, 733-741.

Bildirici, M. (2016). The relationship between hydropower energy consumption and economic growth. *Procedia economics and finance*, *38*, 264-270.

Bildirici, M. E. (2012). The relationship between economic growth and biomass energy consumption. *Journal of Renewable and Sustainable Energy*, *4*(2), 023113.

Bildirici, M. E. (2013). The analysis of the relationship between economic growth and electricity consumption in Africa using the ARDL method. *Energy Economics Letters*, *1*(1), 1-14.

Bildirici, M. E. (2014). Relationship between biomass energy and economic growth in transition countries: panel ARDL approach. *Gcb Bioenergy*, *6*(6), 717-726.

Bozkurt, C., & Akan, Y. (2014). Economic growth, CO2 emissions and energy consumption: The Turkish case. *International journal of energy economics and policy*, *4*(3), 484-494.

Can, H., & Korkmaz, Ö. (2019). The relationship between renewable energy consumption and economic growth: The case of Bulgaria. *International Journal of Energy Sector Management*.

Chowdhury, M. K., Hasan, A., & Wadud, A. (2017). Does Energy Consumption Boost Economic Growth in Bangladesh: Evidence from ARDL Bounds Testing Approach. *Asian Journal of Economics, Business and Accounting*, *4*(1), 1-9.

Chowdhury, R. H., & Alam, M. M. (2023). Dynamic relationship among FDI, capital formation, trade openness, and economic growth in Bangladesh. *IOSR Journal of Economics and Finance (IOSR-JEF), 14*(4), 7-14.

Dantama, Y. U., Abdullahi, Y. Z., & Inuwa, N. (2012). Energy consumption-economic growth nexus in Nigeria: An empirical assessment based on the ARDL bound test approach. *European Scientific Journal*, *8*(12).

Elfaki, K. E., Poernomo, A., Anwar, N., & Ahmad, A. A. (2018). Energy consumption and economic growth: empirical evidence for Sudan. *International Journal of Energy Economics and Policy*, *8*(5), 35.

Faisal, F., Tursoy, T., & Ercantan, O. (2017). The relationship between energy consumption and economic growth: Evidence from a non-Granger causality test. *Procedia computer science*, *120*, 671-675.

Farahani Yazdan, G., & Hossein, S. S. M. (2012). Causality between oil consumption and economic growth in Iran: An ARDL testing approach. *Asian Economic and Financial Review*, *2*(6), 678-686.

Fernandes, K., & Reddy, Y. V. (2020). Energy consumption and economic growth in newly industrialised countries of Asia. *International Journal of Energy Economics and Policy*, *10*(4), 384.

Ghosh, B. C., Alam, K. J., & Osmani, M. A. G. (2014). Economic growth, CO2 emissions and energy consumption: The case of Bangladesh. *International Journal of Business and Economics Research*, *3*(6), 220-227.

Hossain, A. K., & Hasanuzzaman, S. (2012). The impact of energy consumption, urbanization, financial development, and trade openness on the environment in Bangladesh: an ARDL bound test approach. *Shahjalal University of Science & Technology*.

Husain, S. (2016). Testing the Long-run Relationship between CO2 Emission, Energy Consumption and Economic Growth for Bangladesh: An ARDL Bound Testing Approach. *British Journal of Economics*, *12*(2).

Islam, M. S., & Ali, B. A. (2011). Energy consumption and economic development in Bangladesh: an empirical study. *Asia-Pac J Soc Sci*, *2*.

Jamel, L., & Derbali, A. (2016). Do energy consumption and economic growth lead to environmental degradation? Evidence from Asian economies. *Cogent Economics & Finance*, *4*(1), 1170653.

Khan, M. K., Khan, M. I., & Rehan, M. (2020). The relationship between energy consumption, economic growth and carbon dioxide emissions in Pakistan. *Financial Innovation*, *6*(1), 1-13.

Khan, M. K., Teng, J. Z., & Khan, M. I. (2019). Effect of energy consumption and economic growth on carbon dioxide emissions in Pakistan with a dynamic ARDL simulation approach. *Environmental Science and Pollution Research*, *26*(23), 23480-23490.

Khan, S., Peng, Z., & Li, Y. (2019). Energy consumption, environmental degradation, economic growth and financial development in the globe: Dynamic simultaneous equations panel analysis. *Energy Reports*, *5*, 1089-1102.

Khondkar, M. (2014). Solar Home Systems in Bangladesh: Progress and Impending Marketing Issues. *Bangladesh University Journal*, *2*(1), 12-20.

Latief, R., & Lefen, L. (2019). Foreign direct investment in the power and energy sector, energy consumption, and economic growth: Empirical evidence from Pakistan. *Sustainability*, *11*(1), 192.

Lu, W. C. (2017). Electricity consumption and economic growth: Evidence from 17 Taiwanese industries. *Sustainability*, *9*(1), 50.

Masuduzzaman, M. (2012). Electricity consumption and economic growth in Bangladesh: Co-integration and causality analysis. *Global Journal of Management and Business Research*, *12*(11), 46-56.

Mehrara, M. (2007). Energy consumption and economic growth: the case of oil exporting countries. *Energy policy*, *35*(5), 2939-2945.

Musa, K. S., & Maijama'a, R. (2020). Economic growth, energy consumption and environmental pollution in Nigeria: Evidence from the ARDL approach. *Energy Economics Letters*, *7*(2), 61-73.

Nguyen, H. M., & Ngoc, B. H. (2020). Energy consumption-economic growth nexus in Vietnam: An ARDL approach with a structural break. *The Journal of Asian Finance, Economics and Business*, *7*(1), 101-110.

Nyasha, S., Gwenhure, Y., & Odhiambo, N. M. (2018). Energy consumption and economic growth in Ethiopia: a dynamic causal linkage. *Energy & Environment*, *29*(8), 1393-1412.

Pandey, K. K., & Rastogi, H. (2019). Effect of energy consumption & economic growth on environmental degradation in India: A time series modelling. *Energy Procedia*, *158*, 4232-4237.

Rahman, M. H., Ruma, A., Hossain, M. N., Nahrin, R., & Majumder, S. C. (2021). Examine the Empirical Relationship between Energy Consumption and Industrialisation in Bangladesh: Granger Causality Analysis. *International Journal of Energy Economics and Policy*, *11*(3), 121.

Rahman, M. M., & Khondkar, M. (2020). Small and medium enterprises (SME) development and economic growth of Bangladesh: A narrative of the glorious 50 years. *Barishal University Journal of Business Studies*, *7*(1), 9-24.

Sadekin, M. N., Alam, M. M., Moudud-Ul-Huq, S., & Islam, T. (2021). Do energy consumption and environmental degradation (CO2 emissions) matter for economic growth? fresh evidence from a developing economy. *International Journal of Energy Economics and Policy*, *11*(5), 289-297.

Sarker, S., Khan, A., & Mahmood, R. (2016). FDI, economic growth, energy consumption & environmental nexus in Bangladesh. *Econ Appl Inform*, *1*, 33-44.

Saudi, M. H. M., Sinaga, O., Roespinoedji, D., & Jabarullah, N. H. (2019). Industrial, commercial, and agricultural energy consumption and economic growth lead to environmental degradation. *Ekoloji*, *28*(107), 299-310.

Sek, S. (2017). The impact of energy consumption on economic growth: The case of China. *Applied Ecology and Environmental Research*, *15*(3), 1243-1254.

Sharif Chaudhry, I., Safdar, N., & Farooq, F. (2012). Energy Consumption and Economic Growth: Empirical Evidence from Pakistan. *Pakistan Journal of Social Sciences (PJSS)*, *32*(2).

Sriyana, J. (2019). Dynamic effects of energy consumption on economic growth in an emerging economy. *670216917*.

Tariq, G., Huaping, S. U. N., Haris, M., & Yusheng, K. O. N. G. (2018). Energy consumption and economic growth: Evidence from four developing countries. *American Journal of Multidisciplinary Research*, *7*(1).

Twerefou, D. K., Iddrisu, K. S., & Twum, E. A. (2018). Energy consumption and economic growth: evidence from the West African Sub-region. *West African Journal of Applied Ecology*, *26*, 217-233.

Waheed, R., Sarwar, S., & Wei, C. (2019). The survey of economic growth, energy consumption and carbon emission. *Energy Reports*, *5*, 1103-1115.

Wahid, A. N. M., Hossain, A., Mahmud, K. T., & Alom, K. (2017). CO2 emission, power consumption and economic growth in Bangladesh: an ARDL bound testing approach. *The Empirical Economics Letters*, *16*(5), 365-372.