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Electricity Consumption, Capital, Labour, and GDP Growth: An Empirical Evidence from Bangladesh

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Original Article

Abstract. This research examines the short-run, long-run, and joint causal impact of electricity consumption, capital, labour and the GDP growth rate of Bangladesh. Considering previous research, this paper uses the most recent data from 1990 to 2022, when Bangladesh's economy was more stable and experienced continuous growth. Capital and labour are incorporated with electricity to overcome the omitted variable in the growth assessment. Methodologically, the ARDL bound test and Johansen cointegration analysis were used to examine whether electricity and GDP have a long-run association. After that, short-run relationships were examined in both cases. The causality direction identified by the Toda-Yamamoto test addresses the shortcomings of Granger causality. All the methodological steps and tests were further assessed on model stability, serial correlation, normality, and homoskedasticity. Hence, the findings are more robust and policy-oriented. Research findings show unidirectional causality from electricity, capital, and labour to GDP individually and jointly. Hence, all three components should give commensurate importance. Therefore, instead of expensive, heavily subsidised, and short-run solutions, Bangladesh should look at the long-run and cost-effective alternatives for electricity sources.

Keywords: *ARDL, Johansen test, Toda-Yamamoto causality, Electricity Consumption, Growth, Bangladesh*

1. INTRODUCTION

The determinants of economic growth include several potential factors including physical and human capital, institutions, technology, and energy. However, energy has a ubiquitous presence in every aspect of our lives. Electricity plays an epicentre in our all-economic activities. Stern and Kander (2012) in examining the Swedish economy, found that in the last two centuries, energy and energy-based technologies played the most significant role in economic growth. In the last half of the 20th century, labour-based technological improvements became the basis of the growth—energy constraints on the economic growth in the pre-industrial economy (Wrigley, 2013). Power is the primary and fundamental factor that affects development (Ockwell, 2008). Energy is the principal intermediary of the country's economy (Heidari, Katircioglu, & Saeidpour, 2013). Energy consumption and economic growth are affected by several factors. However, its intensity to development depends on how far or close the countries are from a growth perspective. The farther from growth the countries are, the more vital role energy has in development (De Janosi & Grayson, 1972).

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The economic growth of the U.S., the U.K., and Japan during the 20th century shows a non-linear relationship between capital labour and energy with economic growth. From the era of the Industrial Revolution, huge capital stock and inexpensive fossil fuel secured energy availability, which was the main driver of growth. The coefficients of labour, capital, and energy in the generalised production function differ over time (Ayres, Van den Bergh, Linden Berger, & Warr, 2013).

Energy consumption increases by 0.57 per cent if the economy moves forward by one percentage point. However, the consumption responds negatively with 0.03 per cent if the price soars by 1 per cent (Komal & Abbas, 2015). Bangladesh is going through both contradictory phenomena. Despite electricity coverage and production boost, pervasive load shedding phenomena and the absence of backup power supply categorise the on-grid population of Bangladesh hardly as tier 3 from a duration perspective, especially outside the capital. Even in a dire situation, they may fall into the category of tier 0. That means that though people are statistically on the grid, they have no access to electricity (Groh, Pachauri, & Rao, 2016). Though non-substitutable factors like energy have a larger cost-share on output elasticity than that of output elasticity of labour (Kümmel, 2011; Lindenberger & Kümmel, 2011; B. Warr, Ayres, Eisenmenger, Krausmann, & Schandl, 2010; B. S. Warr & Ayres, 2010), the relative importance of energy is much higher.

In recent studies, electricity and economic growth nexus studies explored the nature of the relationship between them. Nisha used panel data from 1990 to 2014 from five South Asian countries and found a significant relationship among international trade, FDI, economic growth, and power usage. They found that increased power consumption causes more investment, which leads to economic growth. Sadiq, Kannaiah, Yahya Khan, Shabbir, Bilal, and Zamir (2023) found a feedback relationship between economic growth and energy use in South Asian countries. Majewski, Mentel, Salahodjaev, and Cierpiał-Wolan (2022) studied panel data of South Asian countries from 19908 to 2018 and found a long-run relationship between electricity supply and economic growth. Their finding suggested improving Bangladesh's energy efficiency without fear of economic growth hampering it.

Wu, Huang, Chiou, Chang, and Chen (2021) found that previous U.S. electricity consumption positively impacted economic growth. However, electricity consumption is negatively affected by the development of the economy. In addition, China and India followed positive and negative feedback between electricity and GDP growth nexus relationship. X. Zhao, Zhang, Zhang, and Hu (2023) stated that economic growth contributes to electricity consumption in China's Yangtze Delta River region. Shameem P, Villanthenkodath, and Chittedi (2022) found that electricity enhances industry and service sector growth in India, adversely affecting the agricultural sector. It shows the growth hypothesis nexus between electricity and GDP. H. Zhang, Zhang, Zhao, and Yuan (2021) studied panel data from 45 B.R.I. countries from 1990 to 2015. They found that high-income countries follow long-run unidirectional causality from economic growth to electricity consumption and bi-directional short-run causalities in OPEC countries. Hassan, Mahmood, and Javaid (2022) found that electricity leads to both short and long-run economic growth in Finland and Portugal, contributing to France's long-run growth.

There is voluminous literature that tried to identify the electricity GDP growth relationship. Most of these studies indicate that causality could flow from electricity to GDP, GDP to electricity, or both. The scenario of omission of significant variables was created using only two variables, which leads to bias and possible misidentification of the causal pattern. Analysis should consider capital, labour, and electricity as essential production factors (Bacon & Kojima, 2016). Omitted variables created bias in the estimation, leading to incorrect inference, and their shortcoming contributes to a lack of coherence in causality testing. Such a wide variety only includes variables determining demand and production apart from energy and GDP (Akkemik & Göksal, 2012; Kalimeris, Richardson, & Bithas, 2014; Ozturk, 2010).

Mozumder and Marathe (2007) and Ahamad and Islam (2011) previously studied electricity consumption and Bangladesh's growth nexus. They used data from 1971 to 1999 and 1971 to 2008, respectively. Both used the Johansen test to identify cointegration and the Granger test to show causality direction. This paper uses additional features than previous studies:

1. Along with capital and labour, electricity is used for the first time as a production factor to overcome omitted variable scenarios.
2. Data from 1990 to 2022, when Bangladesh experienced more stability and growth, are examined in this research.
3. Two different cointegration methods, the modified Granger causality (Toda-Yamamoto) test, were used for methodological soundness and to examine more precise outcomes of the study.

Hence, the findings of this paper are more robust and policy-oriented.

The remainder of the paper is structured as follows. The next section overviews Bangladesh's electricity and GDP growth scenario. A review of the relevant literature, the data and methodological framework of the study, and the empirical results are discussed chronologically. The final section concludes the paper, including policy implications.

2. OVERVIEW OF BANGLADESH'S GDP GROWTH AND ELECTRICITY

Over the last decade, Bangladesh secured a 6 per cent GDP growth rate. Electricity consumption kept its pace. However, it is far below the world standard. The electricity sector comprises three components: production, transmission, and distribution. The Power Grid Company of Bangladesh (PGCB) is the sole electricity transmission entity, and the Bangladesh Power Development Board (BPDB) is the single buyer and seller of electricity. Electricity is sourced from private, public, and joint ventures, three in total, and six distribution companies. Before 1998-99, electricity was generated only by the public sector. After that, the private sector surpassed public sector production from 2010-11 in an ongoing manner. From 2019-20, electricity was also produced as a joint venture project between Bangladesh and others.

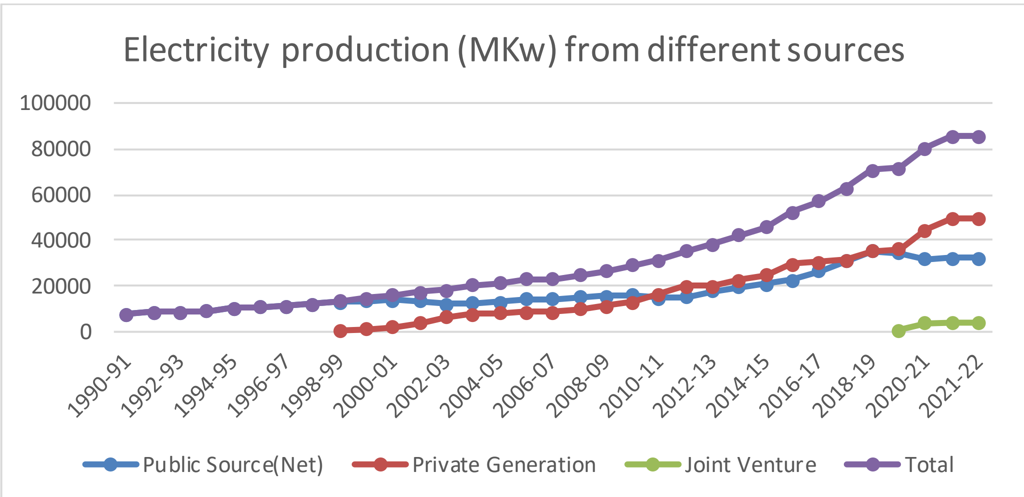

Figure 1. Per Year Electricity Generation by Different Sources

Source: Annual Report, BPDB.

Figure 1 represents a year on the horizontal axis and the total electricity amount on the vertical axis. It shows that electricity generation comprises three sources. The amount of private sector electricity generation is more than that of the public sector. The private sector comprises S/IPP (Small/Independent Power Producer), Rental(s), Rural Electrification Board (REB), and import.

Bangladesh started power import from 2013-14. The public sector comprises BPDB, APSCL, EGCB, NWPGCL, and BPDB-RPCL JV.

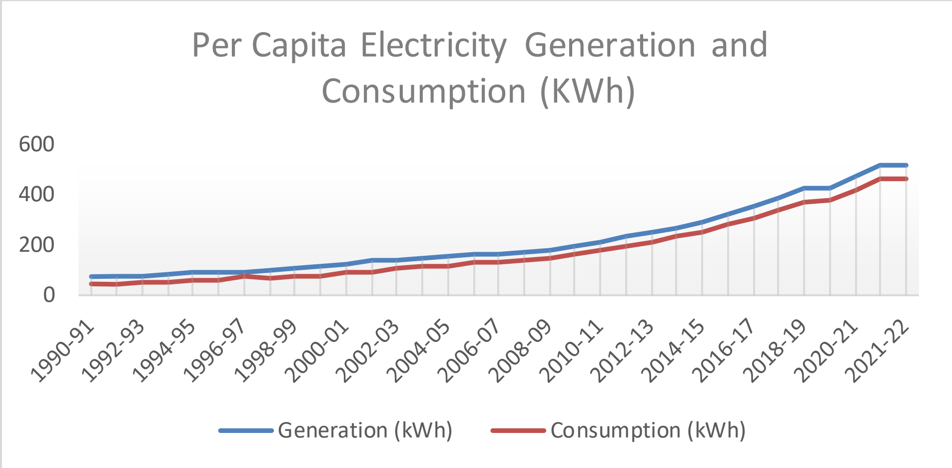

Figure 2. Per capita electricity generation and consumption

Source: Annual Report, BPDB

Figure 2 depicts how Bangladesh's per capita electricity generation and consumption increase over time. Along with the known cause of power transfer, the aged power plant and other reasons created the gap between consumption and generation. To meet the gap in production and the required demand for electricity, rental and S/IPP plants were established — most of these plants are based on oil.

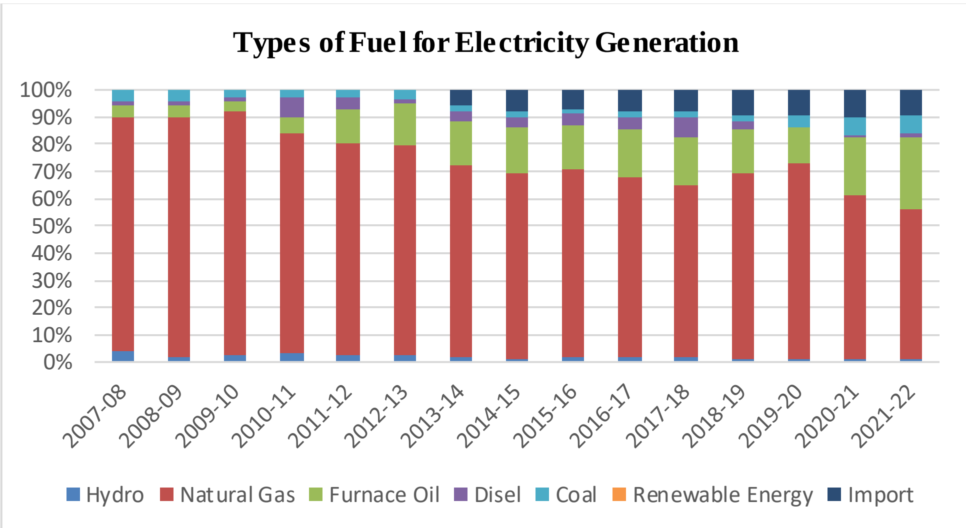

Figure 3. Usage of Fuel in Electricity Generation

Sources: Annual Report, BPDB

Figure 3 illustrates different fuel sources Bangladesh has used for electricity generation. These sources have been diversified over the years. Hydro and renewable energy have the most minuscule contribution to electricity production. Bangladesh has only one hydro source for electricity generation. The main primary fuel for electricity generation is gas. Though gas usage for producing electricity is decreasing subsequently, it still contributes to a significant share. On the other hand, the use of furnace oil and importing electricity is increasing gradually. Fossil fuel contributes to the lion's share of producing electricity in Bangladesh.

Electricity consumers have increased, especially in the last few years. Officially, Bangladesh is entirely electricity-covered, and the consumer scenario is illustrated in Figure 4.

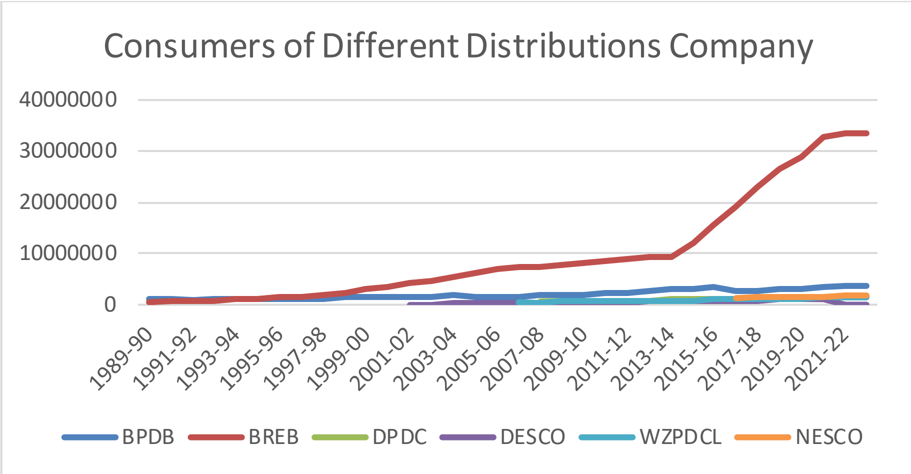

Figure 4. Numbers of consumers from different distribution companies

Source: BPDB Annual Report

Figure 4 portrays the different distribution companies. These companies were established and expanded in different periods. The six distribution companies are BPDB, R.E.B., DPDC, DESCO, WZPDCL, and NESCO. Until 1981, BPDB was solely responsible for distribution. After that, R.E.B. was created, and another four companies were established to meet the increasing demand. The newest one is NESCO.

Along with consumer increase, per capita electricity consumption and GDP also increase. This scenario is represented in Figure 5.

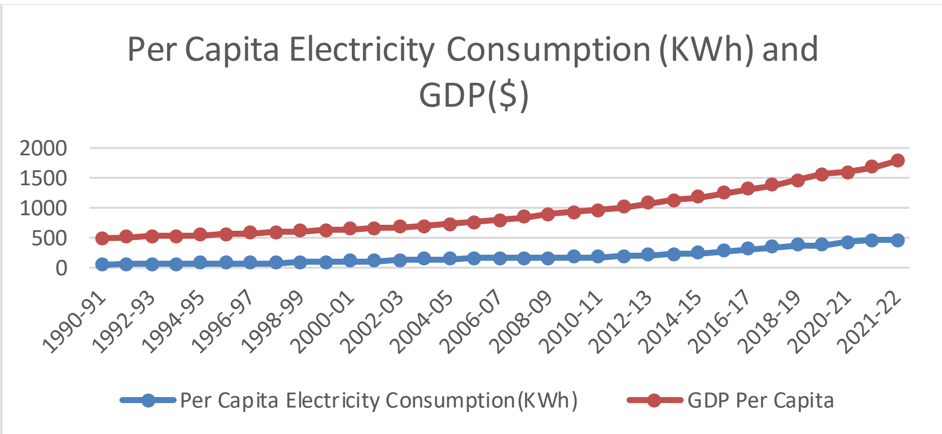

Figure 5. GDP Growth Per Capita and Electricity Consumption

Sources: Annual Report, BPDB; World Development Indicator

Figure 5 indicates the increase in per capita electricity consumption and GDP over time. However, the GDP growth rate per capita increases more than electricity consumption. This consumption is on the grid consumption scenario. Also, households get basic electricity (just for lighting and inadequate fan support) from the solar home system through the off-grid.

3. LITERATURE REVIEW

The causal effect relationship between electricity consumption and economic growth and its direction has no consensus. Developed countries are credited with more research on energy economics than developing countries (Van Ruijven et al., 2008), due to the fact that in developing countries, energy plays a more significant role in economic development. However, energy (electricity) sensitivity to growth has no clear pattern respective to countries or types of countries (Payne, 2010). Omri (2014) found that 40% of the literature on the subject, supported the growth hypothesis, 33% supported the feedback hypothesis, and the rest supported the conservation hypothesis.

Along with growth, electricity to poverty reduction across countries is also heterogeneous. A meta-analysis study by Kalimeris identified 158 studies and 686 cases where they found unidirectional causality from energy to GDP, and GDP to energy at 193 and 163 cases, respectively, with bidirectional causality in 174 studies and no causality in 155 studies.

Future development will be culminated adversely by a lack of energy and material resources (Ayres et al., 2013). Electricity has a strong presence in many production processes as an essential factor (Stern, 2011). Along with the direct contribution to production (Stern, Burke, & Bruns, 2019; Stern et al., 2012), it indirectly facilitates physical capital accumulation (Lechthaler, 2017). Electricity may positively impact growth and employment by increasing productivity (Salmon & Tanguy, 2016). Electrification has a positive broader resonance in society and is beneficial for health and the environment to some extent (Bhattacharya, Paramati, Ozturk, & Bhattacharya, 2016).

Sari and Soytas (2007) found that energy could be more important than labour or capital. Yoo and Lee (2010) identified an inverted U relationship between per capita electricity consumption and income for 88 OECD and developed countries from 1975 to 2004. However, this relationship only exists in non-OECD and developing countries. Renewable and non-renewable electricity generation has a positive and beneficial outcome for economic development in Indonesia (Saudi, Sinaga, Roespinoedji, & Razimi, 2019). Fullerton Jr and Walke (2019) detected unidirectional causality that indicates if capital stock and employment increase, then income on average and electricity consumption will also increase. However, the neutrality hypothesis on the causal impact on electricity consumption and income in the metropolitan area also exists. The neutrality hypothesis for the metropolitan area is supported by previously published research (Chiou-Wei, Chen, & Zhu, 2008; Eden & Hwang, 1984; Eden & Jin, 1992; Payne, 2009). Saunoris and Sheridan (2013) state that in the short run, increased electricity consumption leads to industrial growth (growth hypothesis), but household and business sectors follow the conservation hypothesis.

Mohammadi and Amin (2015) found that the electricity consumption and output of high- and low-growth countries are cointegrated. They find bidirectional causality in the long run for all countries. However, in the short run, causality runs from output to electricity for low- and negative-growth countries. Ghosh (2009) found unidirectional causality from real GDP to electricity supply. This estimate prevails both in the long and short run. Employment and real income granger cause electricity consumption in the long run, though income to electricity consumption and employment is weakly caused (Narayan & Smyth, 2005).

Several types of research have been conducted from the Bangladesh perspective. Ahamad estimated this relationship through vector error correction specified Granger causality using data from 1971-2008 and found unidirectional causality in the short run, which aligned with the growth hypothesis. In the long run, their findings are supported by the feedback hypothesis. Alam, Begum, Buysse, and Van Huylenbroeck (2012) found a vibrant relationship between economic growth and energy consumption. Uninterrupted electricity supply is a pre-requirement for economic development in the long run. Causality direction estimated in both the short and long run indicates that the energy causes economic growth and adequate energy supply propels development positively. This research used data up to 2008. Another research used data from 1980 to 2011 and applied the Maximum Entropy Bootstrap approach (Alam, Ahmed, & Begum, 2017). This study detected unidirectional causality from economic growth to energy consumption, which aligned with the conservation hypothesis. Rahman and Kashem (2017) used data from 1972 to 2011 and performed ARDL and Granger causality tests to detect the linkage of carbon emission, energy consumption, and industrial growth. They found that both industrial production and energy consumption significantly increase carbon emissions. A unidirectional relationship between energy consumption, industrial production, and carbon emission is detected.

On the other hand, Mozumder et al. (2007) estimated the causal relationship between electricity consumption and GDP through Granger causality using data from 1971 to 1999. Their findings align with the conservation hypothesis, meaning electricity consumption is insignificant to economic growth. Narayan and Popp (2012) concluded that the overall impact of energy consumption on real GDP is negative. It is also true for Asia and Bangladesh (Ozturk, 2010). Hence, the existing literature on Bangladesh energy study follows the enigma of world literature.

4. METHODOLOGY

The bivariate model is used heavily in the economic growth and electricity consumption nexus, whereas two variables were economic growth and electricity consumption (Ahamad et al., 2011; Narayan & Singh, 2007; Oh & Lee, 2004; C. Zhang, Zhou, Yang, & Shao, 2017). Consumption of energy augments economic growth and leads to rapid urbanization, but an increased energy price reverses the situation (Komal et al., 2015). Investment decision by the private sector depends on the credibility of politicians and bureaucrats (Yurukoglu & Lim, 2018). Deregulation could lead to a power outage (Lim, 2016), adversely affecting productivity and increasing the household's cost (Pasha & Saleem, 2013; Siddiqui, Jalil, Nasir, Malik, & Khalid, 2008). Electricity and growth could be affected in various ways. However, it is not necessarily justified to use all variables. As this paper examines the causal effect relationship between the variables, it is essential to know the cause and the effect. The examined relationship could be unidirectional or bidirectional or could be unrelated. The causality test will reveal the result.

However, using only two variables for identifying a causal effect relationship could be misleading (Bacon et al., 2016). Ozturk (2010) suggested avoiding such isolated causal effect relations and including factors of production as a control variable to identify the direction of the relationship. Several types of research have been conducted by incorporating both capital and labour with electricity and formed Cobb-Douglas production function to get the answer (Fullerton Jr et al., 2019; Hamdi, Sbia, & Shahbaz, 2014; Lee, Chang, & Chen, 2008; Shahbaz, Hye, Tiwari, & Leitão, 2013; Stern, 2000). When the economy is multi-dimensional, it is logical, even without mathematical proof; electricity, labour, and capital should be regarded as production factors (Ayres et al., 2013). This paper exerts per capita electricity consumption along with labour and capital. Therefore, it becomes the usual Cobb-Douglas production function.

$$Y = AK^{\beta_1} L^{\beta_2} E^{\beta_3} \tag{1}$$

The function of this theoretical basis is followed by some researchers (Best & Burke, 2018; Fullerton Jr et al., 2019; Lechthaler, 2017). In cointegration analysis, Equation 1 is converted into logarithmic form.

4.1 Data and Steps:

The variables in this paper are time series data, and all variables follow a stochastic process. These variables are GDP growth rate (considered as output), capital (Gross capital formation as a percentage of GDP), labour [Labour force participation rate, total (% of total population ages 15-64)], and electricity (per capita electricity consumption). The initial step is the transformed variables stationarity check. Because non-stationary time series data for more than two periods lead to spurious(Yule, 1926)or nonsense regression despite high R square and significant coefficient value, non-stationary data must transform stationary by taking first differences. Steps are described below in Figure6 to draw out causality direction.

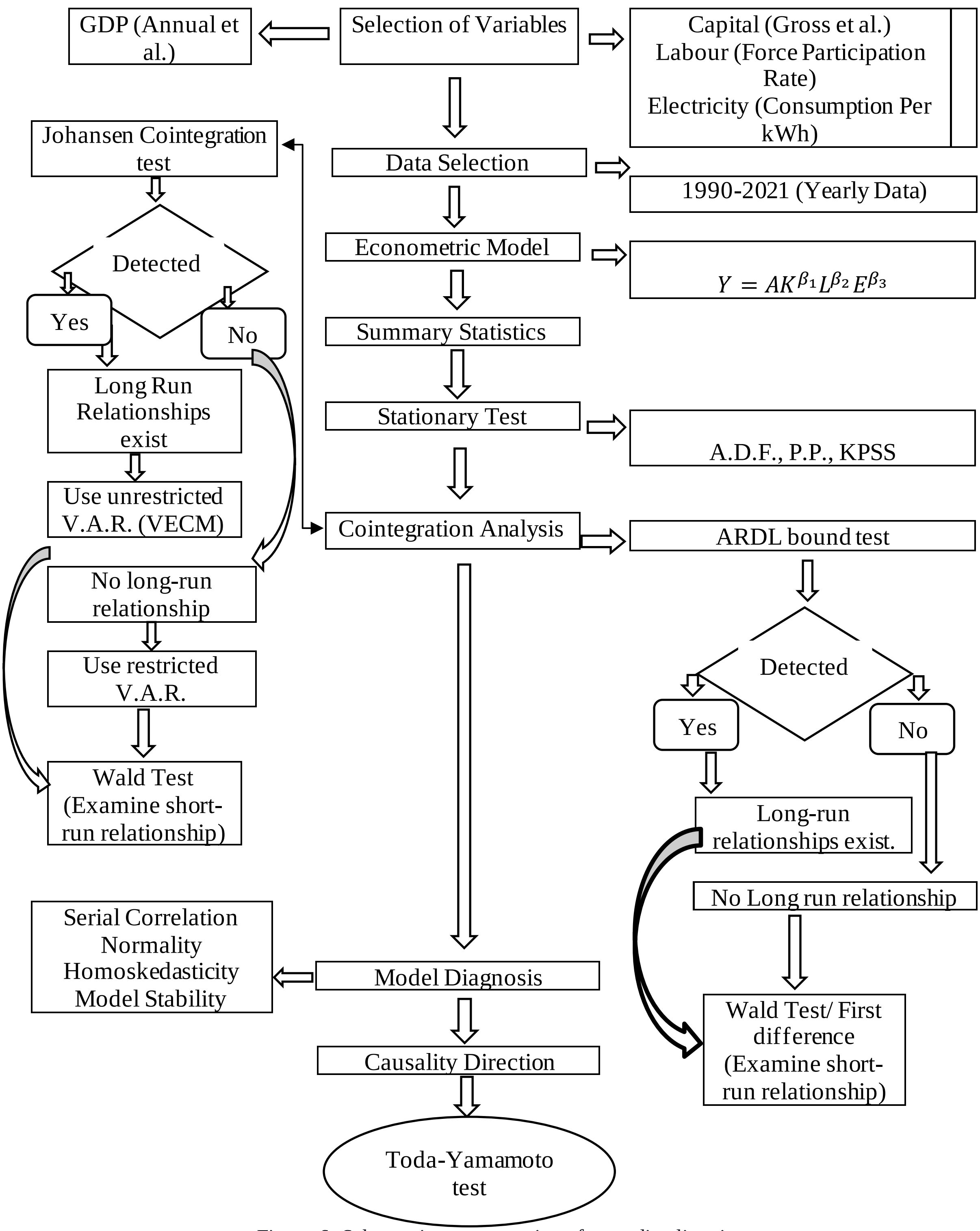

Figure 6. Schematic representation of causality direction

4.2 Stationarity test

Unit root tests have been carried out by Augmented Ducky Fuller (A.D.F.), Philips and Pearson (P.P.), and Kwiatkowski-Phillips-Schmidt-Shin (KPSS). A.D.F. test is conducted including lags, but the P.P. test does not include lag. The null hypothesis for the first two tests is the unit root; however, the KPSS test shows that there is no unit root. All three tests are conducted as unit root characteristics play the most significant role in the time series analysis. A.D.F. includes both drift (constant) and a deterministic time trend. Here, lags are used until serial correlations are driven out. Whether there is a unit root or not is determined by t-statistics. For the A.D.F. test, the equation becomes as follows:

$$\Delta Y_t = \beta_1 + \beta_{2t} + \beta_3 Y_{t-1} + \propto_i \Delta Y_{t-i} + \in_t \tag{2}$$

If both β_1 and β_2 are zero in Equation 2, this will be a random walk equation. If only β_2 is zero, this will be an equation with drift. Lags will be added like $\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2})$ until the presence of serial correlations is removed. The unit root test of the null hypothesis is 'zero.' The t statistics will check H0: β3=0, and a value other than 'zero' means there may be any unit root. Philips and Perron referred to a generalized version of the Dickey and Fuller test as follows:

$$Y_t = \beta_1 + \beta_2 Y_{t-1} + \beta_3 \left(t - \frac{T}{2}\right) + \varepsilon_t \tag{3}$$

In Equation 3, T is the number of observations and ε_t is the error term. P.P. test is non-parametric, robust to heteroskedasticity, and addresses serial correlation. The null hypothesis for KPSS is quite the opposite of the A.D.F. and P.P. tests. This test has been conducted on a complimentary basis.

4.3 *ARDL bound test:*

The ARDL bound test (Pesaran, Shin, and Smith, 2001) will be applied to find out both short-run and long-run dynamics and has several advantages. Whether data follow the I (1) or I (0), the ARDL estimation technique can be applied. It fits better in small sample analysis; different lag lengths can be used for the different variables, provides a more precise unbiased estimation of long-run relationship and parameters, and problems of autocorrelation and endogeneity are taken care of (Harris & Sollis, 2003; Jalil & Ma, 2008). It should be noted that this paper examined the logarithmic transformation of variables.

In this test statistic, the F statistic and cointegrated equation identified the long-run relationship. Following Rahman (2017), Rahman et al. (2017), and Shahbaz et al. (2013), the equation becomes as follows:

$$\Delta Y_t = \propto_0 + \sum_{i=1}^{p} \propto_{1i} \Delta Y_{t-i} + \sum_{i=0}^{q} \propto_{2i} \Delta E_{t-i} + \sum_{i=0}^{r} \propto_{3i} \Delta K_{t-i} + \sum_{i=0}^{s} \propto_{4i} \Delta L_{t-i}$$

$$+ \beta_1 Y_{t-1} + \beta_2 E_{t-1} + \beta_3 K_{t-1} + \beta_4 L_{t-1} + u_t \tag{4}$$

In Equation 4, the coefficients are unrestricted and termed a conditional Error Correction Model (ECM) (Pesaran et al., 2001). The term α represents error correction dynamics, and the term β represents the long-run relationship. This model is lag sensitive, and the appropriate lag length of p, q, r, and s will be determined by the Akaike Information Criterion (AIC), Schwarz Information Criterion (SIC), and others. These lags can be the same (p=q=r=s) or be different. The lag length was selected based on the principle of higher adjuster R square and the lower value of information criterion.

The F statistics test the null hypothesis of no cointegration. I (0) and I (1) represented lower and upper bound values, respectively. Computed values may fall below the lower bound, higher than the upper bound, and in between. For the first case, there is a possibility of no cointegration. For the second one, cointegration exists, and if values fall within the upper and lower bound, it is indecisive. Suppose cointegration is detected in the long run in this research. In that case, Error Correction Dynamics provides a short-run picture of ARDL without compromising long-run information. ECM is formed by the simple linear transformation of ARDL.

$$\Delta Y_t = \delta_0 + \sum_{i=1}^{p} \delta_{1i} \Delta Y_{t-i} + \sum_{i=0}^{q} \delta_{2i} \Delta E_{t-i} + \sum_{i=0}^{r} \delta_{3i} \Delta K_{t-i} + \sum_{i=0}^{s} \delta_{4i} \Delta L_{t-i} + \theta ECM_{t-1} + \mu_t \quad (5)$$

Equation 5 provides the framework of the ARDL model, where θ is the error correction coefficient term.

4.3.1 *Johansen Cointegration Test:*

The Johansen Cointegration test is the maximum eigenvalue and trace test's likelihood ratio test. This test requires all variables to be in the same order of integration to conduct the cointegration test. Unit root test of concerned variables confirms that no variable is following the I (0) process at the level. Hence, the Johansen & Juselius (1990) cointegration test was applied by converting them into the same order of integration, I (1). For the Johansen cointegration test, the variable must be non-stationary at level but will be stationary at first difference. To conduct the procedure, first, the unrestricted V.A.R. model is applied. Here, the vector of variables is related to the past. V.A.R. representation of a vector X_t follows the specification like Equation 6.

$$Y_t = \pi Y_{t-1} + \sum_{i}^{p-1} \varphi_i \Delta Y_{t-i} + \epsilon_t \quad (6)$$

Here, Y_t is n*1 vector of integrated variables,

$$\pi = \sum_{i=1}^{p} A_i - I \quad (6a)$$

And

$$\varphi_i = -\sum_{j=i+1}^{p} A_j \quad (6b)$$

for the number of cointegrating relationships of r, the reduced rank of π must be r<n. Because if r=n, n variables have n cointegrating relationships, and the variables have no unit root. Because each variable's scalar multiplication can generate cointegrating vectors, it implies no unit root. The trace statistics and maximum eigenvalues for the Johansen test are presented in Equation 7 and Equation 8.

$$J_{trace} = -\sum_{i=r+1}^{n} \ln(1 - \hat{\lambda}_i) \quad (7)$$

$$J_{max} = -T \ln(1 - \hat{\lambda}_{r+1}) \quad (8)$$

For trace statistics, the number of the cointegrating vector of the null hypothesis is r; for the alternative hypothesis, it is n. However, for the maximum eigenvalue statistics, the alternative hypothesis is r+1.

4.3.2 *Vector Error Correction Model:*

All variables were I (1) in the Johansen test. However, following the I (0) process at VECM calculation is required. VECM automatically converts variables at first difference. Hence, variables become I (0) as required for calculation. The following designated procedure is finding out 'lag length.' Lag length is based on the criteria of 'the less the value, the better to choose it.' Johansen's cointegration test will be rerun by using the suggested lag length. The difference with the previous test is that here, the optimal lag length is used. Optimal is defined as one less than the suggested lag. If the suggested lag is P, P-1 is the optimal lag in VECM. This is an error correction model, and one lag is already incorporated.

$$\Delta Y_t = \mu_1 + \sum_{i=1}^{n} \alpha_{11} \Delta Y_{t-i} + \sum_{j=0}^{n} \alpha_{12} \Delta K_{t-j} + \sum_{k=0}^{n} \alpha_{13} \Delta L_{t-k} + \sum_{p=0}^{n} \alpha_{14} \Delta E_{t-p} + \theta_1 \Delta ECT_{t-1} + U_{1t} \quad (9)$$

$$\Delta K_t = \mu_2 + \sum_{i=1}^{n} \alpha_{21} \Delta K_{t-i} + \sum_{j=0}^{n} \beta_{22} \Delta Y_{t-j} + \sum_{k=0}^{n} \gamma_{23} \Delta L_{t-k} + \sum_{p=0}^{n} \delta_{23} \Delta E_{t-p} + \theta_2 \Delta ECT_{t-1} + U_2 \quad (10)$$

$$\Delta L_t = \mu_3 + \sum_{i=1}^{n} \alpha_{31} \Delta L_{t-i} + \sum_{j=0}^{n} \beta_{32} \Delta K_{t-j} + \sum_{k=0}^{n} \gamma_{33} \Delta L_{t-k} + \sum_{p=0}^{n} \delta_{34} \Delta E_{t-p} + \theta_3 \Delta ECT_{t-1} + U_{3t} \quad (11)$$

$$\Delta E_t = \mu_4 + \sum_{i=1}^{n} \alpha_{41} \Delta E_{t-i} + \sum_{j=0}^{n} \beta_{42} \Delta K_{t-j} + \sum_{k=0}^{n} \gamma_{43} \Delta L_{t-k} + \sum_{p=0}^{n} \delta_{44} \Delta Y_{t-p} + \theta_4 \Delta ECT_{t-1} + U_{4t} \quad (12)$$

The VECM result shows whether the long-run relationship exists. A statistically significant negative coefficient means a departure from one direction will bounce back in another direction. Hence, it indicates a long-run causality from capital, labour, and electricity to output. In addition, the Wald test will examine the short-run relationship between variables. It uses logistic regression between variables. The null hypothesis is zero, meaning there is no short-term relationship between variables. Chi-square and p-value were gauged to determine the test statistic output.

4.4 *Residual Diagnosis Test:*

Serial correlation, normality, and homoskedasticity tests are used for residual diagnostics. The L.M. statistics and Durbin-Watson d tests are incorporated to detect serial correlation. Two tests are used because no test is unequivocally accepted as best. Serial correlation does not undermine unbiasedness and consistency but efficiency. Positive serial correlation may wrongly reject the null hypothesis. The Durbin-Watson test is expressed by Equation 13.

$$\frac{\sum_{t=i+1}^{T} (\hat{\epsilon}_t - \hat{\epsilon}_{t-1})^2}{\sum_{t=i}^{T} \hat{\epsilon}_t^{\,2}} \quad (13)$$

A histogram test of normality tests the normality condition. It is also a residual-based test, where the Jarque-Bera and p-value are assessed for output. Jarque-Bera uses the following test statistics presented by Equation 14.

$$n\left[\frac{S^2}{6} + (K-3)^2/24\right] \quad (14)$$

Equation 14 follows a chi-square distribution with two digress of freedom. The null hypothesis is that errors are normally distributed; the alternative is that they are not normal. Acceptance of p-value means residuals follow a normal distribution.

Heteroskedasticity presence indicates that any estimation is no longer the best and is contaminated by bias. The Breusch-Pagan-Godfrey test assessed for output diagnosis. It regresses the squared residual on the original regressor. So, Equation 15 expresses the relationship.

$$\hat{u}^2 = \delta_0 + \delta_1 X_1 + \delta_2 X_2 + \cdots + \delta_k X_k + error \quad (15)$$

F statistics, L.M. statistics, and p-value are used to ensure homoskedasticity. The distribution of $F_{k,n-k-1}$, ${\chi^2}_k$, and the critical value of p is based on concluding.

4.5 *Stability Diagnosis:*

Two procedures for the diagnostic test are incorporated. One is the recursive CUSUM, and the other is the CUSUM square (Brown, Durbin, & Evans, 1975) test. Both diagnostics are used by different researchers (Narayan et al., 2005; Pesaran & Pesaran, 1997; Rahman et al., 2017; Yasmeen, Wang, Zameer, & Solangi, 2019).

4.6 *Toda-Yamamoto Causality Test:*

After detecting cointegration and short-run relationships, a causal relationship can show how parameters contribute to economic development. All the four variables, Y_t, K_t, L_t, and E_t, corresponding causal relationships will be checked—first, regress Y_{t+1} using the past values of Y_t, L_t, and E_t. Then $K_t$will included. If the second forecast is statistically significant, it can be concluded that K_t could cause Y_t. F statistics are used to check statistical significance. K_t will be the Granger cause of Y_{t+1} if K_t occurs before Y_{t+1}. In this test, the null hypothesis is that there is no Granger causality, and the alternative hypothesis is that there is Granger causality. The model for the(Toda & Yamamoto, 1995)causality test is specified as follows:

$$Z_t = \phi_0 + \sum_{i=1}^{k+m} \gamma_{1i} Z_{t-i} + \sum_{i=1}^{k+m} \gamma_{2i} X_{t-i} + \eta_{zt} \tag{16}$$

$$X_t = \phi_1 + \sum_{i=1}^{k+m} \sigma_{1i} X_{t-i} + \sum_{i=1}^{k+m} \sigma_{2i} Z_{t-i} + \eta_{xt} \tag{17}$$

Where k is the actual lag order and m is the maximum order of integration. This bivariate analysis examines the direction of the causality from one variable to another.

The traditional Granger causality test has some drawbacks. First, if variables are integrated, correct causal results may not be shown. Second, a change in lag numbers could change the result. On this ground, Toda-Yamamoto Granger causality has some advantages and drawbacks addressed by incorporating two features in the proposed Toda-Yamamoto causality test. This test used the maximum number of integrations and lag length for better output. Test series may not be a single order of integration, non-cointegrated, or cointegrated of any uniform order(Wolde-Rufael, 2005). This test provides more precision than others.

5. RESULT AND DISCUSSION

Thirty-two years of time series data are used in this study in logarithmic form. The summary statistics of data are presented below in Table 1.

Table 1. Descriptive statistics of model variables (1990-2022)

Variables	Obs.	Mean	Std. dev.	Min	Max	Skewness	Kurtosis
LN_GDP	32	6.727	0.382	6.2007	7.429	0.336	1.83
LN_LABOUR	32	4.081	0.012	4.055	4.108	0.112	3.115
LN_ELEC	32	4.837	0.693	3.753	6.045	0.141	1.856
LN_CAPITAL	32	3.202	0.197	2.8008	3.472	-0.604	2.341

Table 1 gives us a glimpse into understanding the data. Now, the next step is conducting a unit root test. Three-unit root tests have been conducted for this test. The unit root result of the test is presented below in Table 2.

Table 2. Unit root test

		ADF		PP		KPSS		
		I	I & T	I	I & T	I	I & T	Decision
Ln_GDP	At level	5.44	-1.452	4.49	-1.452	0.7426(.463)	0.1977(.146)	I (1)
	Δ	-2.99**	-4.74*	-2.96**	-4.74*	0.617(.463)	0.102(.146)	
Ln_Labor	At level	-1.475	-1.475	-1.475	-1.572	0.1073(.463)	0.1113 (.146)	I (1)
	Δ	-5.12*	-5.14*	-5.108*	-5.19*	0.1645(.463)	0.118(.146)	
Ln_Capital	At level	-3.133	-1.761	-3.05	-1.113	0.7163 (.463)	0.1669 (.146)	I (1)
	Δ	-3.015*	-3.70**	-2.97**	-3.47***	0.469 (.463)	0.0715 (.146)	
Ln_Electricity	At level	0.933	-3.052	2.809	-2.873	0.7501(.463)	0.1675(.146)	I (1)
	Δ	-9.183*	-9.265*	-10.57*	-16.84*	0.5(.463)	0.356(.146)	

*, **, and *** indicates level of significance at 1%, 5%, and 10% level. KPSS values are at 5% significance.

The unit root test results indicate that A.D.F. and P.P. reject the null hypothesis of unit root, and KPSS accepts the null hypothesis of no unit root at first difference. The concerned variables follow the integrated order one, I (1) process. This result is significant at a 5% level in most cases. Only capital at the P.P. test (I & T) in one case is significant at 10 %. However, it is significant at 1% and 5% in other tests and cases. Therefore, it is decided that all variables are integrated into one I (1) process. That means variables are non-stationary at the level and stationary at the first difference.

The ARDL (Autoregressive Distributed lag) bound test result is the next step. The ARDL (2,3,4,4) bound upper and lower bounds test values are presented below.

Table 3. ARDL (2,3,4,4) bound test

F Statistics Value	1% Critical value	
	I (0)	I (1)
16.541	3.65	4.66

Source: Author's calculation

The null hypothesis of the ARDL test is that there is no long-run cointegration. No long-run cointegration exists if the F statistics value falls below the I (0) value. The calculated F statistics value is greater than the upper bound value I (1), so there is a long-run cointegrated relationship. Hence, the null hypothesis is rejected and accepts that there is a long-run cointegration in the model. In the previous studies of Bangladesh's electricity consumption and growth nexus, no ARDL approach was used for cointegration analysis. However, researchers found a long-run association between energy and growth (Rahman et al., 2017), energy finance and growth (Mahi, Phoong, Ismail, & Isa, 2019) and industrialization, electricity consumption and carbon emissions (Shahbaz, Uddin, Rehman, & Imran, 2014). Now, the long-run relationship between GDP and other variables is presented below.

Table 4. The long-run relationship between GDP and other variables

Variables	Coefficient	t-Statistics	Prob
Electricity	0.77362	39.02892	0
Capital	-0.58424	-9.47522	0
Labour	0.068805	0.118434	0.9079

The t statistics value and probability show that electricity has a significant relationship with GDP in the long run. The short-run relationship is derived from the ARDL-ECM through the Wald test. The result is stated below in Table 5.

Table 5. The short-run relationship between GDP and other variables

Variables	F-statistics	Prob
Electricity	7.6901	0.002475
Labour	11.3034	0.000489
Capital	8.0741	0.002723

This result shows that electricity has a significant relationship with the GDP in the short run. In addition, the other two variables, labour and capital, also cause short-run GDP growth. That means the ARDL and Wald test confirm the short-run and long-run relationship between GDP and electricity consumption. H. Zhao, Zhao, Han, He, and Guo (2016) found that in North China, a bi-directional causality exists in six provinces between electricity consumption and real GDP except Hebei, capital and economic growth and labour and economic growth except Beijing and Hebei. However, Sarker et al. (2019) found that energy leads to economic growth in Bangladesh assessed with labour and capital.

Another cointegration analysis, namely the Johansen cointegration test, has been conducted to cross-validate and complementary basis. In addition, the previous two research (Ahamad et al., 2011; Mozumder et al., 2007) used the Johansen cointegration test to assess Bangladesh's electricity GDP growth nexus. The result of the Johansen cointegration test is represented in Table 6.

Table 6. Johansen Cointegration result

Cointegrating Equation	Eigenvalue	Unrestricted Cointegration Rank Test (Trace)			Unrestricted Cointegration Rank Test (Max-Eigenvalue)		
		Trace Statistics	5% Critical Value	Prob.	Max-Eigenvalue Statistics	5% Critical Value	Prob.
r=0	0.66866	64.22393	63.8761	0.046	33.138362	32.118316	0.0374
r≤1	0.37248	31.08557	42.9152	0.439	13.979259	25.823210	0.7242

This test used trace and maximum eigenvalue statistics to decide whether they were cointegrated. Based on the result, the null hypothesis of no cointegration is rejected, and there is, at most, one cointegrating vector. Thus, the vector error correction model (VECM) allows the extraction of both long and short-run causality. The long-run causality is represented by Table 7 in the following.

Table 7. The long-run causality result

	Coefficient	Std. Error	t-Statistic	Prob.
C (1)	-0.289979	0.074206	-3.90775	0.001132
R-squared	0.818426	Adjusted R-squared		0.700937
F-statistic	6.965978	Prob(F-statistic)		0.000227

The result of this test statistics shows a negative and statistically significant coefficient C (1), indicating causality running from capital, labour, and electricity to GDP in the long run. It shows the speed of adjustment or error correction response with almost three percentage points. Other values also depict a good fit of the results. Rather than unidirectional causality, Ahamad et al. (2011) show bi-directional causality in the long run. Now, the short-run causality through the Wald test is examined. This result is represented in Table 8.

Table 8. The short-run relationship between GDP and other variables

Variables	F-statistics	Prob
Electricity	5.140878	0.010334
Labour	7.977418	0.003602
Capital	2.750748	0.074704

Table 8 shows that, in the short run, electricity causes GDP growth. This result is aligned with Ahamad et al. (2011). It also shows labour as a contribution to the GDP in the short run. The probability value for capital may not have short-run causality to GDP it aligns with Mozumder et al. (2007). They do not find any causal relationship between electricity and GDP growth. For the validity of the analysis, it needs to diagnose the model. Hence, the different test statistics procedures conducted and their result is described in Table 9.

Table 9. Diagnosis test of ARDL and Johansen model

Test Name	ARDL		Johansen Cointegration		
	F-statistic	Prob.	F-statistic	Prob.	Decision
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.390125	0.95735	1.625317	0.180038	Homoskedasticity
Breusch-Godfrey Serial Correlation LM Test	1.998967	0.191274	0.65049	0.595639	No serial correlation
Jarque-Bera	4.695	0.0956	0.400416	0.818	Normally Distributed

Table 9 indicates that both ARDL and Johansen tests are homoscedastic, no serial correlation exists, and they are normally distributed. That means the test statistics values show that these models are unbiased, consistent, and efficient. In addition, the stability of the model is depicted by the subsequent Figure 7.

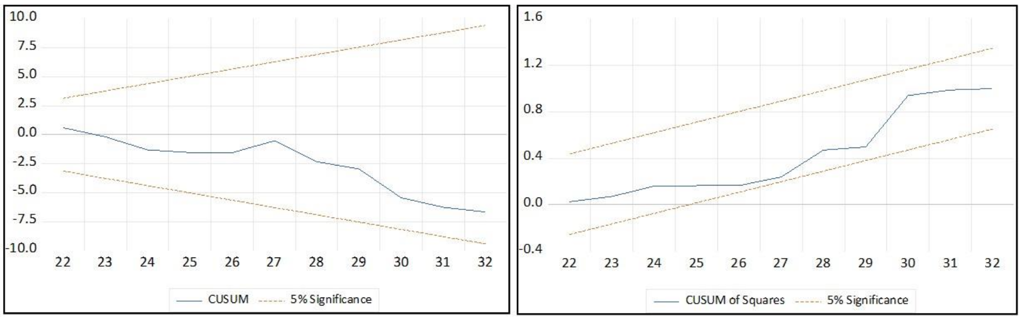

Figure 7. CUSUM and CUSUM of squares test

The CUSUM and the CUSUM of squares test examined model stability. Figure 7 indicates that the model is stable. Both Table 9 and Figure 7 connote that the output of these two models is statistically valid and reliable. As causality in both models is identified, the direction of causality is detected by the Toda-Yamamoto test. The test statistics output of the causality test is presented below in Table 10.

Table 10. Toda-Yamamoto causality test

Dependent Variable	Independent Variable	Chi-square Value	P- value
GDP	Electricity	18.77734	0.0008
	Capital	27.42876	0.00
	Labour	47.95554	0.00
All		136	0.00
Capital	Electricity	6.109829	0.191095
	GDP	22.27797	0.0001
	Labour	21.07605	0.0003
All		45.04208	0.00
Labour	GDP	5.424998	0.246401
	Capital	9.31164	0.053765
	Electricity	5.339892	0.254166
All		9.817472	0.63197
Electricity	GDP	4.356843	0.359861
	Capital	4.811436	0.307198
	Labour	3.014421	0.555415
All		14.70538	0.257945

This result shows that electricity, capital, and labour cause GDP growth altogether and individually. Among the four hypotheses in the electricity growth nexus, this research follows the growth hypothesis found in many cases. This unidirectional causality from electricity to GDP was true for Korea from 1970-99 (Oh et al., 2004); in 18 developing countries (Lee, 2005) and Nigeria (Matthew, Ede, Osabohien, Ejemeyovwi, Fasina, & Akinpelumi, 2018), whereas it found bidirectional causality in Iran (Salmanzadeh-Meydani & Ghomi, 2019). These countries were and are now in the growth stages, as now Bangladesh is. However, our result suggested that GDP does not cause electricity growth. It also shows that GDP and labour can lead to new capital formation. These findings sound logical from an economic point of view. Because increased electricity facilitates more investment, growth (GDP) and labour augment investment, which causes new capital formation. Both ARDL and Johansen models show long-run and short-run causality between electricity consumption and GDP growth. For the direction of causality, the Toda-Yamamoto causality test was used. One of the two previous studies of Bangladesh (Ahamad et al., 2011) concluded that electricity consumption leads to GDP growth in Bangladesh. The findings are consistent with earlier studies (Alam et al., 2012; Apergis & Payne, 2009; Narayan et al., 2007). The authors of the previous studies observed that the unidirectional causality is moving from electricity consumption to GDP growth. However, another Mozumder et al. (2007) study showed that GDP growth causes electricity consumption. This finding is aligned with previous reports (Alam et al., 2017; Narayan et al., 2012; Ozturk, 2010). Between these two different findings, our study supports that electricity consumption causes the GDP growth of Bangladesh. This finding supported the previous outcome of Ahamad et al. (2011).

CONCLUSION AND POLICY IMPLICATIONS

This research examined the data from 1990 to 2022. It incorporated electricity, capital, and labour to address the omitted variable scenario to determine the causal relationship between electricity consumption and GDP growth. Therefore, three different unit root tests of A.D.F., P.P., and KPSS were performed for the stationarity check, followed by the two cointegration tests. It should be noted that the previous two studies about the electricity-growth nexus of Bangladesh examined only the Johansen cointegration and the Granger causality test. In addition to the Johansen test, this research examined the methodologically sounder ARDL test. For causality identification in the short and long run, this research was examined thoroughly by the ARDL bound test, maximum eigenvalue and trace statistics, and Wald test.

Moreover, causality direction is assessed by the Toda-Yamamoto causality test, which addresses the drawbacks of the previously applied Granger causality test. All the procedures are evaluated thoroughly by normality check, serial correlation detection, homoskedasticity identification, and model stability by designated procedures. In every case, statistical output was reliable and could be used further for policy purposes. That means this research is updated from the data and methodological ground and more robust to policy implications.

The evidence of this paper manifested the significance of electricity consumption and suggested it as a prerequisite for GDP growth. Hence, the recent electricity supply and power outage disruption should be considered carefully. Prone to external shocks and volatility in the electricity sector needs to be addressed to maintain and support uninterrupted power supply in Bangladesh. Therefore, incessant external dependency on fuel and the import of electricity requires further assessment since importing raw materials for power requires enormous subsidies. However, Bangladesh has a limited amount of fuel sources, and these are depleting rapidly. In this regard, the government should emphasize solar, wind, and other sources in the short and long run to reduce the dependency on imported fuel.

Additionally, making the Rooppur atomic power plant operational as soon as possible to provide power to the national grid is an effective solution. In addition to electricity, capital and labour have a robust influence on the GDP growth of Bangladesh. Therefore, these two sectors must weigh commensurately.

Bangladesh is now at the crossroads of development. Electricity contributes to GDP growth along with capital and labour. Hence, heavily subsidizing any sector of these three put extra-budgetary pressure on the other sectors. Hence, subsidy in the electricity sector requires thorough examination, especially in the case of short-term projects and quick rentals. Further research can be carried out on how energy-efficient appliances can reduce total energy usage. Bangladesh is now on the way to upgrading from L.D.C. to a developing country. On this very occasion, it requires adequate capital, labour, and electricity to ensure her growth.

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APPENDIX

Table 11. Descriptive statistics of model variables (1990-2022)

Variables	Obs.	Mean	Std. dev.	Min	Max	Skewness	Kurtosis
LN_GDP	32	6.727	0.382	6.2007	7.429	0.336	1.83
LN_LABOUR	32	4.081	0.012	4.055	4.108	0.112	3.115
LN_ELEC	32	4.837	0.693	3.753	6.045	0.141	1.856
LN_CAPITAL	32	3.202	0.197	2.8008	3.472	-0.604	2.341

Table 11 gives us a glimpse of the understanding of data. It shows all the observations and their mean, standard deviation, minimum and maximum values, skewness, and kurtosis.

Table 12. Unit root test

		ADF		PP		KPSS		
		I	I & T	I	I & T	I	I & T	Decision
Ln_GDP	At level	5.44	-1.452	4.49	-1.452	0.7426(.463)	0.1977(.146)	I (1)
	Δ	-2.99**	-4.74*	-2.96**	-4.74*	0.617(.463)	0.102(.146)	
Ln_Labor	At level	-1.475	-1.475	-1.475	-1.572	0.1073(.463)	0.1113 (.146)	I (1)
	Δ	-5.12*	-5.14*	-5.108*	-5.19*	0.1645(.463)	0.118(.146)	
Ln_Capital	At level	-3.133	-1.761	-3.05	-1.113	0.7163 (.463)	0.1669 (.146)	I (1)
	Δ	-3.015*	-3.70**	-2.97**	-3.47***	0.469 (.463)	0.0715 (.146)	
Ln_Electricity	At level	0.933	-3.052	2.809	-2.873	0.7501(.463)	0.1675(.146)	I (1)
	Δ	-9.183*	-9.265*	-10.57*	-16.84*	0.5(.463)	0.356(.146)	

*, **, and *** indicates level of significance at 1%, 5%, and 10% level. KPSS values are at 5% significance.

The unit root result of the test is presented in Table 12. These test results indicate that A.D.F. and P.P. reject the null hypothesis of unit root, and KPSS accepts the null hypothesis of no unit root at first difference. The concerned variables follow the integrated order one, I (1) process. This result is significant at a 5% level in most cases. Only capital at the P.P. test (I & T) in one case is significant at 10%. However, it is significant at 1% and 5% in other tests and cases. Therefore, it is decided that all variables are integrated into one I (1) process.

Table 13. ARDL (2,3,4,4) bound test

F Statistics Value	1% Critical value	
	I (0)	I (1)
16.541	3.65	4.66

The null hypothesis of the ARDL (2,3,4,4) test result in Table 13 shows a long-run cointegration. The calculated F statistics value is greater than the upper bound value I (1), so there is a long-run cointegrated relationship.

Table 14. The long-run relationship between GDP and other variables

Variables	Coefficient	t-Statistics	Prob
Electricity	0.77362	39.02892	0
Capital	-0.58424	-9.47522	0
Labour	0.068805	0.118434	0.9079

The long-run relationship between GDP and other variables is presented in Table 14. The t statistics value and probability show that electricity has a significant relationship with GDP in the long run.

Table 15. The short-run relationship between GDP and other variables

Variables	F-statistics	Prob
Electricity	7.6901	0.002475
Labour	11.3034	0.000489
Capital	8.0741	0.002723

The short-run relationship is derived from the ARDL-ECM through the Wald test, as stated in Table 15. This result shows that electricity has a significant relationship with the GDP in the short run. In addition, the other two variables, labour and capital, also cause short-run GDP growth. That means the ARDL and Wald test confirm the short-run and long-run relationship between GDP and electricity consumption.

Table 16. Johansen Cointegration result

Cointegrating Equation	Eigenvalue	Unrestricted Cointegration Rank Test (Trace)			Unrestricted Cointegration Rank Test (Max-Eigenvalue)		
		Trace Statistics	5% Critical Value	Prob.	Max-Eigenvalue Statistics	5% Critical Value	Prob.
r=0	0.66866	64.22393	63.8761	0.046	33.138362	32.118316	0.0374
r≤1	0.37248	31.08557	42.9152	0.439	13.979259	25.823210	0.7242

The result of the Johansen cointegration test is represented in Table 16. This test used trace and maximum eigenvalue statistics to decide whether they were cointegrated. Based on the result, the null hypothesis of no cointegration is rejected, and there is, at most, one cointegrating vector. Thus, the vector error correction model (VECM) allows the extraction of both long and short-run causality.

Table 17. The long-run causality result

	Coefficient	Std. Error	t-Statistic	Prob.
C (1)	-0.289979	0.074206	-3.90775	0.001132
R-squared	0.818426	Adjusted R-squared		0.700937
F-statistic	6.965978	Prob(F-statistic)		0.000227

The long-run causality is represented by Table 17. The result of this test statistics shows a negative and statistically significant coefficient C (1), indicating causality running from capital, labour, and electricity to GDP in the long run. It shows the speed of adjustment or error correction response with almost three percentage points. Other values also depict a good fit for the results.

Table 18. The short-run relationship between GDP and other variables

Variables	F-statistics	Prob
Electricity	5.140878	0.010334
Labour	7.977418	0.003602
Capital	2.750748	0.074704

Table 18 shows that, in the short run, electricity causes GDP growth. It also shows labour as a contribution to the GDP in the short run. They do not find any causal relationship between electricity and GDP growth. For the validity of the analysis, it needs to diagnose the model.

Table 19. Diagnosis test of ARDL and Johansen model

Test Name	ARDL		Johansen Cointegration		
	F-statistic	Prob.	F-statistic	Prob.	Decision
Heteroskedasticity Test: Breusch-Pagan-Godfrey	0.390125	0.95735	1.625317	0.180038	Homoskedasticity
Breusch-Godfrey Serial Correlation LM Test	1.998967	0.191274	0.65049	0.595639	No serial correlation
Jarque-Bera	4.695	0.0956	0.400416	0.818	Normally Distributed

Table 19 indicates that both ARDL and Johansen tests are homoscedastic, no serial correlation exists, and they are normally distributed. That means the test statistics values show that these models are unbiased, consistent, and efficient.

Table 20. Toda-Yamamoto causality test

Dependent Variable	Independent Variable	Chi-square Value	P- value
GDP	Electricity	18.77734	0.0008
	Capital	27.42876	0.00
	Labour	47.95554	0.00
All		136	0.00
Capital	Electricity	6.109829	0.191095
	GDP	22.27797	0.0001
	Labour	21.07605	0.0003
All		45.04208	0.00
Labour	GDP	5.424998	0.246401
	Capital	9.31164	0.053765
	Electricity	5.339892	0.254166
All		9.817472	0.63197
Electricity	GDP	4.356843	0.359861
	Capital	4.811436	0.307198
	Labour	3.014421	0.555415
All		14.70538	0.257945

The test statistics output of the causality test is presented in Table 20. This result shows that electricity, capital, and labour cause GDP growth altogether and individually. Among the four hypotheses in the electricity growth nexus, this research follows the growth hypothesis found in many cases. These findings sound logical from an economic point of view. Because increased electricity facilitates more investment, growth (GDP) and labour augment investment, which causes new capital formation. Both ARDL and Johansen models show long-run and short-run causality between electricity consumption and GDP growth. For the direction of causality, the Toda-Yamamoto causality test was used.