Examining the Relationship between Rural and Urban Populations’ Access to Electricity and Economic Growth: A New Evidence

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Abstract: The electric power industry has a dominant contribution to economic development in China, and growth in the industry needs to help the economy grow, protect the environment, and give people access to electricity. The current study’s main goal is to assess the rural and urban populations’ access to electricity, energy use, and economic development in China using yearly data ranging from 1995 to 2017. We applied two unit root tests to check the variables’ stationarity and a symmetric autoregressive distributed lag (ARDL) approach to discover the variable links using long-run and short-run estimates. The Granger causality test was also used in this study under a vector error correction model (VECM) to assess the variables’ unidirectional connection. Short-run results demonstrate that total population access to electricity, urban population access to electricity, and energy use have positive links with economic development, with probability values of (0.004), (0.000), and (0.007), respectively. Similarly, long-run evidence shows that variables such as total population access to electricity, urban population access to electricity, and energy use have a positive relationship with economic growth, with p-values of (0.005), (0.000), and (0.047), respectively. Unfortunately, throughout the investigation, the variable electricity availability to the rural population demonstrated an adverse relationship with China’s economic growth. Furthermore, the Granger causality test results under the vector error correction model (VECM) show that all variables have unidirectional links. China’s implementation of new plans regarding energy consumption has a significant impact on both future energy supply and the country’s ability to stay sustainable. It will be able to maintain the stability of its energy levels as long as it sticks to suitable choices and policy options. Undoubtedly, China is a huge user of energy and an emitter of CO2 emissions; therefore, possible conservative strategies and policies are required from the Chinese government to use clean energy sources to fulfill its energy demand.

Keywords: energy use; economic growth; electricity consumption; environmental sustainability; urban population

1. Introduction

Environmental issues and global warming have thrust China into the limelight because of its size and growing economic influence throughout the world over the last four decades. There is a growing concern among the general public, government authorities, and international organizations about the rapid use of energy and emissions of greenhouse gases [1]. Numerous studies have shown that electricity consumption is a significant indicator of economic and social advancement, despite the fact that economic theory has failed to explain the relationship between energy usage and economic growth. Increased
electrical consumption may boost capital, labor, and technology development to some extent, which in turn can boost power demand [2,3]. China’s rapid economic rise since 1978, encompassing industrialization, information technology, urbanization, and agricultural modernization, has been unprecedented. The industrial economy’s rapid rise has been fueled by increased energy consumption. Coal, oil, natural gas, and other fossil fuels are rapidly replacing coal as China’s principal energy source [4,5].

Electricity is the most widely used and efficient source of energy on the planet. Electricity consumption is greater in industrialized economies. Over the previous few decades, there has been a technological boom, all of which has made electricity a necessary input to get things done. Electricity has historically been a significant energy resource because it is easily produced, stored, and supplied across longer distances [6]. The surge in electricity usage has substantial implications for business and public policy. Increased energy use normally boosts power company profits, but expanding conventional power plants to meet increased demand may exacerbate pollution and other environmental challenges. One cannot deny that increased energy consumption has resulted in considerable productivity advances that have aided the economy, nor did earlier economic expansion result in increased power consumption. However, the one-to-one relationship between energy consumption and gross domestic product (GDP) does not seem to be applicable anymore [7,8]. Although significant progress has been made in recent decades in linking the world’s residents to a reliable supply of energy, several regions continue to be gravely neglected. To justify the actions of development organizations and governments to improve power supply and reliability, it is useful to know that such intervention will have a causal effect on economic growth, poverty, and other important development indices [9]. Furthermore, China is the world’s largest coal user and second largest electricity consumer, accounting for 28.74 percent and 16.67 percent of total consumption in 2007. Furthermore, China’s economy continues to grow rapidly, with the gross domestic product (GDP) increasing by an average of 8% per year over the previous 30 years, with levels of energy consumption and global warming reflecting it [10]. Over the previous two decades, China’s economy has grown significantly, surpassing the United States as the world’s second-largest power user. With the growth of electrification, electricity has become a necessary input for industrial and office work, as well as a prerequisite of modern life, as characterized by the constant replacement of other energy types. Since 1990, the proportion of total end-user energy consumption accounted for it through electricity in China has increased significantly. Trends in energy and electricity intensity may potentially indicate the existence of electricity substitution effects. While energy intensity decreased by more than half between 1978 and 2004, electricity intensity decreased by only 15 percent, indicating an increase in electricity utilization as a source of energy [11,12].

The electricity sector is vital to the development of the Chinese economy since it is the country’s primary source of energy. The growth of the electricity sector aims to support economic progress, encourage environmental sustainability, and provide energy to the general population. In emerging countries, the goal of supporting economic growth is critical. The utilization of electricity is a vital contribution to urban economic growth and industrialization [13,14]. This is the first and only study to prove the correlation between China’s economic development and electricity usage in rural and urban population areas, according to the authors’ knowledge. The primary goal of this analysis is to provide a unique contribution to the existing body of knowledge concerning the connection between China’s increasing electricity consumption and the country’s economy. In addition, it would be beneficial to provide suggestions on how China might save energy, increase energy efficiency, and achieve long-term economic development. We utilized the time series data for analysis, and connection amid variables was checked by utilizing the symmetric autoregressive distributed lag (ARDL) technique with long-run and short-run estimations. Further, unidirectional causality amid variables was checked by utilizing the VECM-based Granger causality test.
The rest of the paper structure is laid out as follows. In Section 2, we briefly discuss the related literature on the existing topic. Study methods and materials are represented in Section 3 with model specifications. Section 4 focuses on empirical outcomes and discussions. Finally, the conclusions and recommendations section summarizes the whole study.

2. Existing Literature

In recent decades, both global energy use and demand have continuously climbed. Emerging economies and developing countries are seeing faster economic development. Global energy consumption is growing mostly as a consequence of population growth and urbanization. The increased usage of energy, especially nonrenewable sources such as coal and oil, has had a huge impact on our world. Regional environmental pollution and large-scale ecological deterioration have harmed the economy’s and human civilization’s long-term development [15–17]. The causes driving the power-intensive review include increased energy demand in response to sectoral changes and transitions in manufacturing performance, quality of life, and economic growth. These include the significance and use of electric power in the economy as it transitions from an agrarian to an industrial sector and provides societal benefit. When it comes to economic growth, the electricity sector is critical not just for industrial development but also for enhancing people’s quality of life. Total energy consumption has a less substantial link with prosperity than wealth production has with total energy consumption. The investigation also found a high association between export diversification and per capita power use and production in emerging countries [18–20].

Because machinery, transportation, and commodity manufacturing all need considerable amounts of energy, they may be seen as vital components of modern economic advancement. All of our social and economic activities, however, rely on the usage of energy. Electricity is a serious issue in rural areas, especially in developing countries, in the twenty-first century. Rising populations and emerging economies are driving up energy consumption in these regions. Consumers who lack even the most basic types of electricity need quick assistance [21–23]. Energy, a critical component in the manufacturing process, is seen as a contributor to economic progress alongside money, labor, and technology. A continuous energy supply is required to maintain and grow current output levels, and any energy deficit would have a negative impact on economic development. Countries can only achieve a particular step of economic growth by using a certain amount of energy. It looks difficult to produce goods and services, manage industrial processes, or deliver them successfully and efficiently to customers if you lack energy. Because energy is a crucial component needed at every stage of production, any disruption in energy procurement or an increase in energy demand that cannot be met to enhance output under favorable conditions may result in economic bottlenecks. Economic development influences a country’s energy consumption, and it may also affect its GDP [24–26].

Many production and consumption activities need the use of energy as a critical input. Energy availability is crucial for economic success. There can be no contemporary economy without energy since it is a physical component of every modern economy [27]. Because of two characteristics, dependability may be more important in urban areas than in rural ones. For starters, cities have a far higher population density. As a result, adding new customers will be less expensive, illegal grid connections will be easier, and neighbors will be able to share electrical connections more readily. This indicates that access rates in cities are already much higher than in rural areas. Simultaneously, urban issues such as overcrowding and electricity theft may make it difficult to maintain high levels of reliability. Second, rather than agriculture, which is the mainstay of rural economies, urban production is more likely to be concentrated on manufacturing and services. Because of the significance of electricity in industry, cities may face higher opportunity costs in the event of a power outage [28,29]. Increasing the supply and use of energy services is a crucial component of improving economic development. In highly industrialized nations, more energy is utilized per unit of economic output and per capita than in poorer societies, especially
those that are still in a preindustrial condition of affairs. The quantity of energy required to generate one unit of output has decreased through time as a result of more efficient energy generation and consumption, as well as changes in the structure of the economy. Energy intensity in developing economies is predicted to peak sooner and at lower levels than during the industrialization of advanced economies. As a consequence, despite attempts to enhance energy efficiency and other disincentives, total and per capita energy consumption in advanced economies continues to grow, with emerging economies predicted to expand even faster as incomes rise [30,31].

The energy business is significantly reliant on electricity. However, there is currently little evidence that the power industry directly helps economic growth in developing countries. As more items are introduced to the market during this technologically advanced era, the amount of electricity utilized in houses has increased. This, on the other hand, deviates from industry standards. Power shortage has prompted large corporations to build power plants. Countries’ growing reliance on electric power underscores the most pressing problem with time, i.e., how to meet global demand for energy [32,33]. The goal of sustainable development is growing increasingly dependent on energy accessibility. According to the neoclassical paradigm, energy neutrality is difficult since the emergence of modern energy sources directly benefits people’s lives while indirectly benefiting the economy. When electricity is easily accessible as a primary energy source, a country’s ability to meet domestic and household energy needs, as well as its export potential, grows [34].

As a result, overall socioeconomic progress improves. Almost everything we manufacture or consume is dependent on energy in some manner. Despite the fact that neoclassical growth models presuppose land, labor, and capital as the primary sources of production inputs, this is a contentious issue. Energy plays a critical role in economic growth via liberalization, privatization, and globalization. Because energy plays a vital role in the creation of money and employment, it should be addressed when considering qualities. Oil demand is increasing, as is our reliance on foreign energy supply and the harmful impact of CO\textsubscript{2} emissions on the environment [35,36].

Every year, the rate of global population growth grows substantially. This rise has an impact on electricity demand for housing, state progress, and other purposes. As a consequence of these advances, there must be enough energy to meet all of our needs while also protecting the environment. Forecasting power use is critical for saving energy and protecting the environment [37,38]. Because of the scarcity of fossil fuels for power generation and the expanding population, energy has become one of the most critical requirements of this century. Energy-saving measures are becoming increasingly popular as people become more aware of and concerned about environmental issues. This indicates that all countries confront the world’s most serious energy crisis. The principal source of energy in the twenty-first century is produced by massive thermal power plants. This energy is generated using long consumer-facing transmission lines and distributed to clients through the distribution system. The lack of proper load model information while planning and performing different network inspections is a key source of worry for energy distribution companies. To guarantee accurate distribution network design and management calculations, adequate user load models must be used [39,40].

3. Materials and Methods

We examined rural and urban populations’ access to electricity and economic development in China using yearly data sets ranging from 1995 to 2017. As a consequence of our investigation, we obtained the data from the World Bank (https://data.worldbank.org/country/CN) (accessed on 25 May 2022), and the variables used are: access to electricity of the total population, access to electricity of the urban population, access to electricity of the rural population, energy use, and economic growth. The data trends are explored in Figure 1 year wise, while Figure 2 illustrates the historical trend of the electric power consumption in China. The methodological framework for this investigation is demonstrated in Figure 3. First, we tested the descriptive analysis for the variables with correlation.
analysis. After that, two unit root tests, including DF-GLS and P-P, were employed to check the variables’ stationarity, and then bounds testing to cointegration with the Johansen cointegration technique were used. In the next step, a symmetric technique was applied with the estimations of short-run and long-run analyses. In the end, a Granger causality test was carried out under VCEM in order to discover the unidirectional links that existed between the variables.

Figure 1. Plot of the variables’ trend.

Figure 2. Scenario of electric power consumption in China.
3.1. Econometric Model and Data Sources

We examined the impact of access to electricity of the rural and urban populations, and energy use on the economic growth of China, and the following model can be stated as:

\[
ECG_t = \tau_0 + \tau_1 AEP_t + \tau_2 AERP_t + \tau_3 AEUP_t + \tau_4 ENUS_t + \varepsilon_t
\]  

(1)

We can write Equation (1) further as:

\[
\ln(ECG_t) = \tau_0 + \tau_1 \ln(AEP_t) + \tau_2 \ln(AERP_t) + \tau_3 \ln(AEUP_t) + \tau_4 \ln(ENUS_t) + \varepsilon_t
\]  

(2)

where Equation (2) shows that, \(ECG_t\) = economic growth; \(AEP_t\) = access to electricity of the total population; \(AERP_t\) = access to electricity of the rural population; \(AEUP_t\) = access to electricity of the urban population; \(ENUS_t\) = energy use; and \(t\) = measurement of time with the long-run model coefficients \(\tau_1-\tau_4\).

The long-term relationships between nonstationary sequences have been solved by Engle and Granger (1987) [41], autoregressive distributed lag to cointegration techniques or bounds tests for cointegration [42], Johansen and Juselius (1990) [43] cointegration techniques, and their re-specification into error correction model (ECM). The short-term dynamics and long-term running interactions of the underlying variables are shown by the re-specification of the outcomes. Traditional estimation methods are still used by most investigators even if it is compulsory to test for the connection between the variables’ considered cointegration, despite the versatility of cointegration techniques in estimating the relationship between nonstationary variables and reconciling short-term dynamics with long-term equilibrium. Cointegration is a useful test, but many investigators are acquainted with the parameters under which it is appropriate to use and how to interpret the findings.

Furthermore, the ARDL method, developed by Pesaran et al. (2001) [44], was used to find correlations between the variables examined in this research as well. The ARDL model may be used to examine the data if there are long-term associations between the variables. Consequently, when a variable is stationary I(1), the restrictions are no longer relevant. The ARDL model provides an effective correction for inaccurate regressions caused by missing or omitted variables. This study examined long-run and short-run connections between
economic growth and various parameters. An ARDL model with an error correction model is required if we are seeking cointegration, and the model with lags is specified as follows:

\[
\Delta \text{LnECG}_t = \gamma_0 + \sum_{g=1}^{g} \beta_g \Delta \text{LnECG}_{t-g} + \sum_{g=0}^{g} \tau_g \Delta \text{LnAERP}_{t-g} + \sum_{g=0}^{g} \xi_g \Delta \text{LnAEUP}_{t-g}
\]

\[
+ \sum_{g=0}^{g} \theta_g \Delta \text{LnAEUP}_{t-g} + \sum_{g=0}^{g} \lambda_g \Delta \text{LnENUS}_{t-g} + \varphi_1 \text{LnECG}_{t-1} + \varphi_2 \text{LnAERP}_{t-1} + \varphi_3 \text{LnAEUP}_{t-1} + \varphi_4 \text{LnENUS}_{t-1} + \epsilon_t
\]

In Equation (3), the letter “g” indicates the order of the lags. In a similar vein, error correction model, which may be stated as follows, can be used to investigate the short-run dynamics that exist between the variables.

\[
\Delta \text{LnECG}_t = \gamma_0 + \sum_{g=1}^{g} \beta_g \Delta \text{LnECG}_{t-g} + \sum_{g=0}^{g} \tau_g \Delta \text{LnAERP}_{t-g} + \sum_{g=0}^{g} \xi_g \Delta \text{LnAEUP}_{t-g}
\]

\[
+ \sum_{g=0}^{g} \theta_g \Delta \text{LnAEUP}_{t-g} + \sum_{g=0}^{g} \lambda_g \Delta \text{LnENUS}_{t-g} + \varphi_1 \text{LnECG}_{t-1} + \varphi_2 \text{LnAERP}_{t-1} + \varphi_3 \text{LnAEUP}_{t-1} + \varphi_4 \text{LnENUS}_{t-1} + \text{ECT}_{t-1} + \epsilon_t
\]

The short-run error correction representation of the model is shown in Equation (4).

### 3.2. Granger Causality Technique under Vector Error Correction Model (VECM)

The autoregressive distributed lag model was used to examine the cointegration consistency of this model over the short and long term. The findings revealed undefined correlations between variables, and variable sources were also tracked by causal verification of the vector error correction model, which shows their relevance in current values. The VECM model was created by Engle and Granger (1987) to categorize and identify causal linkages. An error correction model (ECT) will be used for short-term testing if the models given comprise autoregressive distributed lag (ARDL) or vector error correction model (VECM). As a consequence of this framework, the short-term causal review should contain an error correction term (ECT) in cases where the pace of adjustment makes obtaining the genuine long-term symmetrical position in this model challenging at this moment. Under the VECM model, cointegration is not necessary for VAR techniques to undertake causality checks. As a result, the VECM standard model is used to establish the causal relationship between the embodied variables, as follows:

\[
\begin{bmatrix}
\Delta \text{LnECG}_t \\
\Delta \text{LnAERP}_t \\
\Delta \text{LnAEUP}_t \\
\Delta \text{LnENUS}_t \\
\Delta \text{LnECG}_{t-1} \\
\Delta \text{LnAERP}_{t-1} \\
\Delta \text{LnAEUP}_{t-1} \\
\Delta \text{LnENUS}_{t-1}
\end{bmatrix} =
\begin{bmatrix}
\Psi_1 \\
\Psi_2 \\
\Psi_3 \\
\Psi_4 \\
\Psi_5
\end{bmatrix}
+ \begin{bmatrix}
\varphi_{11}, \varphi_{12}, \varphi_{13}, \varphi_{14}, \varphi_{15}, \varphi_{16} \\
\varphi_{21}, \varphi_{22}, \varphi_{23}, \varphi_{24}, \varphi_{25}, \varphi_{26} \\
\varphi_{31}, \varphi_{32}, \varphi_{33}, \varphi_{34}, \varphi_{35}, \varphi_{36} \\
\varphi_{41}, \varphi_{42}, \varphi_{43}, \varphi_{44}, \varphi_{45}, \varphi_{46} \\
\varphi_{51}, \varphi_{52}, \varphi_{53}, \varphi_{54}, \varphi_{55}, \varphi_{56}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
\varphi_{17} \\
\varphi_{27} \\
\varphi_{37} \\
\varphi_{47} \\
\varphi_{57}
\end{bmatrix}
\]

\[
+ \begin{bmatrix}
\delta_1 \\
\delta_2 \\
\delta_3 \\
\delta_4 \\
\delta_5
\end{bmatrix}
\]

In the above Equation (5), \(\Delta\) specifies the operator that demonstrates the difference. \(\delta\) shows the error term classification, and \(\xi\) explores the error term (ECT\(_{t-1}\)) coefficient.
4. Empirical Outcomes and Discussion

4.1. Descriptive Statistics and Variables Correlation

Table 1 displays the results of the descriptive statistics for all variables in the investigation. Energy use has the highest maximum and minimum values of (7.743) and (6.602). Furthermore, the skewness of economic growth and electricity access to the total, rural, and urban populations have negative values of (−0.731), (−0.386), (−0.162), and (−0.866) respectively. Table 2 provides evidence of the connection among the variables by demonstrating that there is a correlation between all of the variables.

Table 1. Descriptive analysis.

|       | LnECG | LnAEP | LnAERP | LnAEUP | LnENUS |
|-------|-------|-------|--------|--------|--------|
| Mean  | 2.220 | 4.574 | 4.559  | 4.603  | 7.146  |
| Median| 2.235 | 4.577 | 4.559  | 4.603  | 7.082  |
| Maximum| 2.655 | 4.605 | 4.605  | 4.605  | 7.743  |
| Minimum| 1.362 | 4.524 | 4.496  | 4.597  | 6.602  |
| Std. Dev.| 0.277 | 0.026 | 0.035  | 0.002  | 0.423  |
| Skewness| −0.731| −0.386| −0.162 | −0.866 | 0.173  |
| Kurtosis| 4.523 | 1.883 | 1.766  | 2.492  | 1.374  |
| Jarque-Bera| 5.207 | 2.153 | 1.899  | 3.803  | 3.224  |

Table 2. Correlation amid variables.

|       | LnECG | LnAEP | LnAERP | LnAEUP | LnENUS |
|-------|-------|-------|--------|--------|--------|
| LnECG | (1.000)| −0.140| −0.187 | −0.074 | −0.188 |
| LnAEP | −0.140| (1.000)| 0.993  | 0.958  | 0.953  |
| LnAERP| −0.187| 0.993 | (1.000)| 0.934  | 0.969  |
| LnAEUP| −0.074| 0.958 | 0.934  | (1.000)| 0.849  |
| LnENUS| −0.188| 0.953 | 0.969  | 0.849  | (1.000)|

4.2. Unit Root Testing amid Variables

The DF-GLS and P-P tests [45,46] were used to make sure that the variables’ stationarity was complete before commencing the regression analysis. It is revealed in Table 3 that both of these tests had key findings. In this investigation, variables, such as I (0), were demonstrated to exhibit horizontal continuity throughout the duration of a lengthy period of time. After this, the values of these variables remained fixed at I (1). In terms of the order of integration, the model contains not only variables from the I (0) series but also variables from the series I (1). After gaining encouraging results from unit root testing, we turn to the ARDL approach for an empirical investigation. The ARDL technique allows for the inclusion of integral variables in cointegration analysis. In this case, the hypothesis is rejected, and the surrogate for no unit root is accepted.

Table 3. Unit root testing.

|       | LnECG | LnAEP | LnAERP | LnAEUP | LnENUS |
|-------|-------|-------|--------|--------|--------|
| Probability values * with Test statistics | −1.998 | −1.122 | −0.786 | −0.615 | −1.753 |
| Probability values * with Test statistics | −0.738 | −0.392 | −5.506 | −6.998 | −2.059 |
| Probability values * with Test statistics | −3.962 | −4.039 | −2.012 | −4.431 | −0.008 |
| Probability values * with Test statistics | −8.359 | −1.182 | −5.386 | −7.000 | −2.786 |

Note: * specifies the p-values at level.
4.3. Bounds Test to Cointegration

The ARDL to cointegration method does not need prior testing for the unit roots, unlike other strategies. In a small sample size of I (0), I (1), or a combination of the two, when there is a single long-term connection between two underlying variables, ARDL to cointegration techniques are preferred. In order to evaluate whether there was a long-term interaction between the underlying variables, the F-statistic (Wald’s test) had to be applied. It is characterized as an F-statistic over the crucial value range for the long-term interaction of the data set. Even when there are several cointegration vectors, this technique can find cointegration matrices. Because I (2) has an integral stochastic trend, this approach does not work in this case. The outcomes of bounds test to cointegration are represented in Table 4. When it comes to relevance, this study found that the upper and lower limits of cointegration were 10%, 5%, 2.5%, and 1% of the level, and the value of the F-statistic was (5.486). The use of bond tests to create integrals reveals the long-term interplay of variables and their linkages in this technique.

Table 4. Bounds test to cointegration results.

| [F-Bounds Testing] | Founds no Levels Relationship at Null Hypothesis |
|---------------------|--------------------------------------------------|
|                     | [Critical Values]  | [Lower Bound I (0)]  | [Upper Bound I (1)] |
| F-statistic value   | [5.486]           | 2.2                  | 3.09                |
|                     | [10%]             | 2.56                 | 3.49                |
|                     | [5%]              | 2.88                 | 3.87                |
|                     | [2.5%]            | 3.29                 | 4.37                |

The Dickey–Fuller test is an extension of the Johansen test in that it includes a large number of variables. A generalization is a linear combination of variables used to find a problem of the unit root. Using the Johansen test and the estimation technique maximum likelihood, it is feasible to estimate all cointegration vectors in the presence of more than two variables. Only control dimensions, each with a unit root, may have dual cointegration vectors. When n variables have unit roots, there are only (n−1) cointegration vectors that may be found. All cointegrated vectors are estimated via Johansson’s test. The presence of a unit root, such as the Dickey–Fuller test, indicates that the standard asymptotic distribution does not apply [47]. Furthermore, based on trace and the maximum eigenvalue test, the assumption of no cointegration equations in the model was excluded at the 5% level of significance. Using cointegration, we may see how closely related the variables under study are across time. Because of this, some factors may be combined. There are long-term correlations between most variables, and null hypotheses may be rejected. Table 5 displays the results of the J-cointegration test.

Table 5. J-cointegration technique outcomes.

| Trace Test | E-Value | T-Statistic | C-Values at (0.05) | Prob. Values ** | Hypo-No. of CE(s) |
|------------|---------|-------------|--------------------|----------------|------------------|
| Trace      | 0.814   | 103.962     | 69.818             | 0.000          | None *           |
|            | 0.688   | 60.126      | 47.856             | 0.002          | At most 1 *      |
|            | 0.526   | 29.780      | 29.797             | 0.050          | At most 2        |
|            | 0.225   | 10.322      | 15.494             | 0.256          | At most 3        |
|            | 0.132   | 3.694       | 3.841              | 0.054          | At most 4        |

| Maximum Eigenvalue Test | E-Value | Max-Eigen Statistic | C-Values at (0.05) | Prob. Values ** | Hypo-No. of CE(s) |
|-------------------------|---------|---------------------|--------------------|----------------|------------------|
|                         | 0.814   | 43.835              | 33.876             | 0.002          | None *           |
|                         | 0.688   | 30.345              | 27.584             | 0.021          | At most 1 *      |
|                         | 0.526   | 19.458              | 21.131             | 0.084          | At most 2        |
|                         | 0.225   | 6.627               | 14.264             | 0.534          | At most 3        |
|                         | 0.132   | 3.694               | 3.841              | 0.054          | At most 4        |

Note: * The hypothesis denial at the 0.05 level is shown; ** Indicates the MacKinnon–Haug–Michelis p-values (1999).
4.4. Symmetric (ARDL) Technique Outcomes

Table 6 demonstrates the influence of the symmetric technique. Short-run outcomes show that variables access to electricity of the total and urban population, and energy use has positive coefficients of (8.038), (43.196), and (0.409) with probability values of (0.004), (0.000), and (0.007) respectively, that exhibited a dynamic relation to the economic growth of China. The variable access to electricity of the rural population revealed a negative connection to economic growth.

Table 6. Linear ARDL technique outcomes.

| Variables   | Coefficients | Standard Error | Test Statistic | p-Values |
|-------------|--------------|----------------|----------------|----------|
| C           | −173.126     | 151.376        | −1.143         | 0.269    |
| LnGDPG(−1)  | −0.492       | 0.123          | −3.976         | 0.001    |
| LnAEP       | 8.038        | 10.985         | 0.731          | 0.004    |
| LnAERP      | −14.125      | 7.547          | −1.871         | 0.079    |
| LnAEUP      | 43.196       | 37.743         | 1.144          | 0.000    |
| LnENUS(−1)  | 0.409        | 0.310          | 1.317          | 0.007    |
| D(ENUS)     | 2.047        | 0.660          | 3.100          | 0.006    |
| CointEq(−1) | −0.492       | 0.074          | −6.572         | 0.000    |

| Variables   | Coefficients | Standard Error | Test Statistic | p-Values |
|-------------|--------------|----------------|----------------|----------|
| LnAEP       | 16.334       | 22.840         | 0.715          | 0.005    |
| LnAERP      | −28.704      | 14.646         | −1.959         | 0.077    |
| LnAEUP      | 87.776       | 77.554         | 1.131          | 0.000    |
| LnENUS      | 0.832        | 0.546          | 1.522          | 0.047    |
| C           | −351.800     | 316.662        | −1.110         | 0.283    |

Stability Tests

|             |             | Adjusted R²    |               |          |
|-------------|-------------|----------------|---------------|----------|
| R²          | 0.864       |                | 0.813         |          |
| Log likelihood | 28.105     | F-statistic    | 17.017        |          |
| Prob(F-statistic) | 0.000     | AIC            | −1.835        |          |
| Schwarz     | −1.489      | HQC            | −1.748        |          |
| criterion   | 2.112       |                |               |          |
| D-Watson stat |           |                |               |          |

Moving towards the outcomes of the long-run estimation exposes the variable access to electricity of the total population and urban population and energy utilization has positive coefficients of (16.334), (87.776), and (0.832), with probability values of (0.005), (0.000), and (0.047), which show the constructive relationship with economic growth of China. Unfortunately, in the long run, variable access to electricity of the rural population indicates a negative relationship with economic growth. Electricity is the best-quality source of energy, and its share of total energy usage is increasing. Electricity consumption, in conjunction with its participation in productive activities, is seen as an indicator of socioeconomic progress. The recent growth in energy prices, the depletion of present resources, and the search for new energy sources and energy-efficient technologies have prompted discussion of the connection between energy consumption and economic advancement. Energy is an important factor in industry and economic development. Power outages caused by load shifting in the area had a substantial effect on enterprises in all three sectors: commercial, industrial, and agricultural. This ultimately has a considerable influence on the country’s economic growth, with severe consequences for unemployment and social circumstances [48]. Improving energy efficiency has been one of the top priorities in most countries, and as a result, considerable progress has been made in increasing energy efficiency. That is why primary energy consumption is growing at a slower rate than total economic activity. The significant decrease in energy intensity might be attributed to rising energy prices, technological advancements, and government energy regulations [49].
China’s usage of fossil fuels has skyrocketed in recent years, owing in part to the country’s rapid industrialization, urbanization, and economic expansion. Energy consumption and carbon emissions are anticipated to rise as a consequence of urbanization and migration, putting a strain on the energy infrastructure. Increasing renewable energy power output and increasing electricity consumption are critical steps toward lowering greenhouse gas emissions. In recent years, China’s power demand has increased dramatically, but the proportion of conventional fossil fuel production has declined significantly [50–52].

Electricity has always been the backbone of economic progress and is a key infrastructural contribution to social and economic expansion. The world faces a boom in electricity consumption driven by significant causes such as population expansion, extensive urbanization, industrialization, and growing living standards [53]. The carbon emissions from power generation in a region depend on the volume and mix of electricity output. The kind of source blended or employed influences the carbon intensity of the quantity of CO₂ released per unit of power. Exponential increases in energy consumption and fast increases in pollutant emissions are predicted to have evident repercussions on the global environment: increasing global temperatures, instability in temperature and severe weather, and changes in ecosystems and habitats. All of these consequences offer growing problems for energy production and usage and have an increasing role in the design of future energy systems and energy policy [54,55]. Likewise, the demand for economic expansion leads to environmental deterioration, which is typically the outcome of development and industrialization in both emerging and developed economies. Economic development in every nation relies on many variables that might adversely affect the environment, such as unsustainable natural resource exploitation, environmental degradation, and climate change. In addition, the fast development in urbanization in many countries has hastened economic growth, resulting in greater energy consumption. Therefore, a crucial challenge confronting many nations is the carbon dioxide content of the atmosphere, which is growing considerably due to energy use and economic expansion. Fossil fuels, including coal, natural oil, and natural gas, are the primary source of energy, and they also lead to greater carbon dioxide emissions [56,57].

In recent years, there has been an increasing link between sustainable development and energy resource management and planning. Demand for fossil fuels far outstrips availability, and the cost of imports is growing. It is imperative that we develop low-cost, efficient, and ecologically friendly sources of energy at this time. An emphasis on renewable energy sources is not unexpected. Sustainable economic progress and social well-being need the use of renewable energy. Every energy state has a predetermined output factor. Economic growth is also desperately required because of the country’s reliance on oil [58,59]. Economic development may be aided by the use of energy. Because many industrial processes need energy, energy is an important driver of economic development. On the other hand, as the economy grows, so does the need for more goods and services, including an increased quantity of oil. Every region should be examined to better understand how its energy use influences human activity and development. Energy supplies are fast depleting as the world population grows and people’s materialistic lifestyles change. Earth’s climate and ecosystems have been adversely affected by an increase in global energy usage. Fossil fuels are a major contributor to pollution since they are the primary source of energy. The fact that oil production and consumption are on the rise indicates that energy will continue to be a major global concern in the future. Energy sources that are both environmentally friendly and sustainable are required to satisfy this need. Renewable energy sources, such as solar and wind, will assist in closing the gap without contributing to the emission of greenhouse gases or causing damage to the environment [60–62]. The outcomes of the stability test show that the statistical values of $R^2$, adjusted $R^2$, F-Stat., Akaike info criterion, and Durbin–Watson statistics are (0.864), (0.813), (17.017), (−1.835), and (2.112). Figure 4 illustrates the CUSUM and its squares plot with stable trends at the 5% significance level.
In recent years, there has been an increasing link between sustainable development and industrial processes. Energy, being an important driver of economic development, has become a major global concern. Economic growth is also desperately required due to the country's reliance on energy. Renewable energy sources, such as solar and wind, will assist in closing the gap between the demand and supply of energy. Global energy usage is increasing, and fossil fuels are a major contributor to pollution. As the world population grows, so does the need for energy. Consequently, the availability of scarce resources is depleting, and the cost of imports is growing. It is imperative that we develop low-cost, efficient, and ecologically friendly sources of energy.

Table 7 explores the impacts of stability and diagnostic testing. Breusch–Godfrey serial correlation and heteroskedasticity tests’ F-values and p-values are (0.367), (0.479) and (0.698), (0.813) respectively. Furthermore, the criterion and histogram normality test plot is illustrated in Figure 5.

Table 7. Stability and diagnostic test.

| Tests                                      | F-Statistics | Prob. Values |
|--------------------------------------------|--------------|--------------|
| [Serial Correlation LM Test of Breusch–Godfrey] | 0.367        | 0.698        |
| [Harvey Heteroskedasticity Test]           | 0.479        | 0.813        |
| [CUSUM test]                               | Stable       |              |
| [CUSUM of Squares test]                    | Stable       |              |

Figure 4. CUSUM and its squares at 5% significance.

4.5. Granger Causality Test under VECM Outcomes

Table 8 provides a description of the outcomes of the Granger short-term causality test. These outcomes include the cointegration findings, which provide the variable connections that are utilized to examine directional causality via regressors. The ARDL approach illustrates the long-term links that exist among the variables being studied. In addition, the short-term Granger connections point to the primary influence that plays a role in...
directing the ultimate conclusion, and the indicators determine that there is a unidirectional connection among economic growth and other study variables. Therefore, Granger’s causality-based VECM demonstrates that there is a significant connection between the factors that were taken into consideration.

Table 8. Granger causality test under VECM.

| Dependent Variables | ΔLnECG | ΔLnAEP | ΔLnAERP | ΔLnAEUP | ΔLnENUS |
|---------------------|--------|--------|---------|---------|---------|
| ΔLnECG              | -      | 2.674  | 5.774 **| 0.000   | 0.719 **|
| ΔLnAEP              | 1.255  | -      | 5.094 **| 1.410   | 2.047   |
| ΔLnAERP             | 0.593  | 6.586  | -       | 0.936   | 1.399   |
| ΔLnAEUP             | 0.235 *| 1.781  | 3.071   | -       | 1.740   |
| ΔLnENUS             | 0.898  | 2.489  | 2.374 * | 0.704   | -       |

Note: *, ** reveals at 1% and 5% significance.

In addition, the trends of the variance decomposition analysis and impulse response indicate up to 100 periods for all variables are illustrated in Figure 6, which indicates access to electricity of the total population, access to electricity of the rural and urban populations, and energy use in China.

![Figure 6. Plots of variance decomposition analysis and Impulse response.](image-url)

5. Conclusions and Recommendations

We determined the impact of electricity access on the rural and urban populations, energy usage, and economic growth in China. The unit root tests were used to verify the stationarity of the variables. Links between variables were discovered using an autoregressive distributed lag method, and a Granger causality test under a vector error correction model was also utilized to examine for unidirectional links among the variables. Findings from both the short run and long run show that access to electricity of the total urban population and energy usage have positive linkages to economic growth in China. The variable access to electricity of the rural population revealed an adversative connection and led to economic growth. Furthermore, the findings of the Granger causality technique under VECM expose that all variables have a unidirectional association. There is no doubt that China consumes a lot of energy and emits a lot of CO₂. It is critical that the Chinese government adopts realistic and conservative plans and strategies in order to satisfy the country’s energy demands as efficiently as possible by utilizing renewable resources.

Despite China’s strong economic expansion, demand for electricity has risen sharply as a result. In China, the government sets the price of electricity, which results in a large
number of subsidies. The government’s strategy of inexpensive energy pricing has led to an increase in power shortages in China as a consequence of a rise in the cost of coal. As a consequence, the most critical component of the country’s energy price reform is the restructuring of power subsidies. People’s everyday consumption and production are intertwined, making reform a particularly challenging task. The world’s greatest user of energy is still China. Coal is still the major source of primary energy and greenhouse gas emissions. The country’s energy requirements are expanding as its economy expands rapidly. If current trends continue, China’s oil production will keep increasing. To build a global energy market, its national oil corporations are merging with and purchasing other international oil corporations. China will continue to search for oil and gas in the coming decade, but coal will remain China’s principal source of energy. Despite China’s high oil and coal output and reserves, the country is now seeing a rapid rise in energy consumption. Energy efficiency, encouraging natural gas, strengthening natural gas supply and technology, and promoting renewable energy are China’s key energy policies. There is a lot of work being done by the government right now to support local as well as regional industry, storage, and long-term supply agreements with international oil producers. Chinese home appliances are predicted to become more energy efficient in the future. The government has made significant investments in solar output, large-scale wind capacity, and waste energy as sources of renewable energy. Implementing the strategy will have a significant impact on China’s future energy supply and sustainability. As long as it makes the correct decisions and strategies, it will be able to maintain its energy stability.

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