Electricity Consumption and Economic Growth: Evidence from South Asian Countries

Sebastian Majewski 1, Urszula Mentel 2, Raufhon Salahodjaev 3,* and Marek Cierpiał-Wolan 4

1 Department of Sustainable Finance and Capital Markets, Institute of Economics and Finance, University of Szczecin, 71-101 Szczecin, Poland; sebastian.majewski@usz.edu.pl
2 Department of Projects Management and Security Policy, Faculty of Management, Rzeszow University of Technology, 35-959 Rzeszow, Poland; u.mentel@prz.edu.pl
3 Department of Mathematical Analysis, Tashkent State University of Economics, 49 O'zbekiston Shoh Ko'chasi, Tashkent 100066, Uzbekistan
4 Department of Quantitative Methods and Economic Informatics, Institute of Economics and Finance, University of Rzeszów, Statistical Office in Rzeszów, 35-959 Rzeszow, Poland; m.wolan@stat.gov.pl
* Correspondence: r.salahodjaev@tsue.uz

Abstract: The purpose of this study is to shed light on the nexus between electricity supply and economic growth in South Asian countries during 1990–2018. The study employs Pedroni’s panel cointegration test as well as Dumitrescu and Hurlin’s (DH) causality test for panel data. The empirical results confirm a long-term relationship between electricity supply and economic growth. We fail to reject the non-causal relationship between electricity supply and economic growth for the panel, thereby affirming the neutrality hypothesis. Single country causality analysis reveals the growth hypothesis in the case of Pakistan. These results have a number of policy implications. For example, governments can introduce measures to improve energy efficiency in Bangladesh, India and Sri Lanka without fear of harming economic growth. The results for Pakistan may also imply that fostering green energy generation would lead to a positive effect on economic growth via improved electricity production. The government may use various policy tools to stimulate adoption of renewable energy, such as fiscal incentives, low interest loans, or grants for rural populations to speed up the green energy transformation.

Keywords: electricity consumption; economic growth; South Asia

1. Introduction

Energy sufficiency is an important factor in the economic development of any country [1–3]. It is a trump card that allows improved capital and labor productivity, development of alternative sources of energy, and thereby enhancement of the status of a country in the international arena. A plethora studies have documented that various types of energy consumption are positively related to economic growth but the most debated question is the direction of the causal relationship [4]. The research on the causal relationship between economic growth and energy consumption dates back to a pioneering study by Kraft and Kraft [5], in which authors assessed this nexus using data from the USA. While the growth–energy association has significant policy implications, related literature suggests that there are four types of causal relationship between energy and economic growth, namely the neutrality, conservation, growth, and feedback hypotheses [6–11]. Akarca and Long [12] state that the neutrality hypothesis does not imply any connection between energy consumption and economic growth, and consequently, energy use does not lead to economic growth and vice-versa. According to Gozgor et al. [13], the conservation hypothesis suggests that economic growth is causal to energy consumption, thus policies aimed at efficient energy use will not hamper economic growth. In contrast, the advocates of the growth hypothesis document that there is unidirectional causality running from energy use to GDP growth and
that energy is a significant factor in economic performance [14]. The feedback hypothesis implies a bidirectional nexus between energy consumption and economic growth [15–17].

Taking into account that natural resources are viewed as one of the engines of economic progress, the empirical literature on the link between various types of energy and economic growth has proliferated over the past decades. These studies highlight gas, oil, coal, nuclear, and renewable energy as potential factors affecting economic growth in developed and developing countries [18]. Another strand in existing literature investigates the role that electricity consumption plays in economic growth [19]. The aim is to contribute to the growing strand of research on the electricity–GDP growth nexus by exploring the causal relationship between electricity and GDP growth across four South Asian countries.

There are several arguments that highlight the importance of exploring this relationship. First, overall, GDP growth rates in these countries exceed the world average rate. For example, the average GDP growth in this region over the period 1990–2017 was 5.7% compared to 4.9% in middle-income countries or 4.1% in the Middle East and North Africa. Thus, it is important to identify the variables that predict strong economic performance in these countries. At the same time, per-capita energy consumption across countries in our sample is significantly below global averages. Therefore, energy reforms may have significant potential to boost economic growth in the region. Finally, these countries’ growing population size, and therefore, their demand for energy is likely to increase in the mid-term horizon. For example, the urbanization rate in this region would lead to increased demand for energy. Therefore, it is important to assess the energy–GDP nexus for South Asian countries.

The rest of the study is structured in the following way. Section 2 provides a brief review of related research and Section 3 presents data and the empirical model. Section 4 presents the results of econometric analysis and Section 5 concludes the manuscript.

2. Review of Related Literature

The empirical research on the relationship between electricity sector and economic growth can be split in two groups. The first group of studies attempts to identify the direction of causality between electricity and economic growth using the cointegration method of analysis. While the majority of studies show that there is bidirectional causality between electricity and economic growth [20–25], others show that electricity is causal to economic growth [26–29]. At the same time, a few studies fail to find significant relationship between electricity and growth [30].

The second group of studies relies on the Granger causality test to identify the causal effect of electricity on economic growth. Ghosh [31], using data for India over the period 1950–1997 found that economic growth is causal to electricity consumption. A study by Tang [32], re-visited the electricity–growth nexus for Malaysia using quarterly data for 1972–2004. The results suggest that there is bi-directional causality between electricity and economic growth which needs to be accounted for in long-term strategic documents. In a follow up study, Tang and Tan [33] found that innovation has an effect on economic growth and electricity demand, and there is long-run bidirectional causality between electricity and growth. The authors highlight the crucial role of technological innovations in fostering energy efficiency and long-term economic growth. The role of electricity and economic growth has also been explored in the context of carbon emissions for BRICS countries for the years 1990–2010 by Cowan et al. [34]. The results are mixed. For Brazil, India and China the authors failed to find a significant relationship, while bi-directional causality was observed for Russia and unidirectional causation from growth to electricity for South Africa. Another study assessed the role of Internet usage in the context of the electricity–growth debate [35]. The authors found that ICT development impacts both GDP and electricity demand, while economic growth stimulated the development of the electricity sector in Australia.

Shahbaz and Lean [36] assessed the relationship between electricity and GDP growth in Pakistan. The study found that there is bidirectional causality between electricity and economic growth, suggesting that “adoption of electricity conservation policies to conserve
Energy resources may unwittingly decline economic growth and the lower growth rate will in turn further decrease the demand for electricity” (p. 146). Narayan and Smyth [37] explored the relationship between electricity, GDP and exports in Middle Eastern countries for the years 1974–2002. The study shows that overall, there is a bidirectional relationship between electricity and economic growth. The authors highlight that it is crucial to consider the role of the energy sector in macro-economic forecasting. Wolde-Rufael [38], using a sample of 17 African countries over the period of 1971 and 2001, concludes that the direction of causality differs in each country of the sample. Toda and Yamamoto’s modified Granger causality test and a cointegration test developed by Pesaran et al. [39] show that there is long-run cointegration between electricity consumption and economic growth in 9 out of 17 countries. Causality was found in 12 out of 17 countries. The neutrality hypothesis is proved in the cases of Algeria, Republic of Congo, Kenya, South Africa, and Sudan. A group of countries including Benin, Gabon, Egypt, Morocco, and Tunisia show results in favor of the growth hypothesis. An analysis of Zambia, Zimbabwe, Nigeria, Senegal, Ghana, and Cameroon showed results that support the growth hypothesis.

Yuan et al. [40] assessed the causality among electricity, oil, and coal and economic growth in China for the period from 1963 to 2005 by applying the Granger causality test. The study supports the idea that electricity and oil consumption have significant unidirectional causality to economic growth in the long run. In the short run, GDP affects oil, coal, and total energy consumption (conservation hypothesis), and results do not confirm the causal relationship between electricity and economic growth. Similarly, Shahbaz et al. [21], using data from Portugal from 1971 to 2009, find that electricity consumption, employment, and economic growth are cointegrated between each other and move together in the long run. Moreover, applying a vector error-correction model (VECM) and the Granger causality test, the authors found that there is bi-directional causality between electricity consumption and economic growth in the long run. At the same time, GDP causes electricity use in the short run. Kasperowicz [41] explores the relationship between electricity and economic growth in Poland, using annual data for the period 2000–2012. The author, estimating from a one-industry production model, reports that there is bi-directional causality between electricity demand and economic growth. Considering Poland’s energy outlook, it seems that electricity is an inhibiting aspect of economic growth. Manigandan et al. [42] uses SARIMA-X model to forecast natural gas consumption in the context of the socio-economic development of the US and concludes that in the long run it is necessary to invest in sustainable energy resources such as green or nuclear energy. Rehman et al. [43] explore the relationship between nuclear and coal energy, urbanization, and economic growth in Pakistan over the period 1972–2019. Using a VECM model, the study concludes that nuclear energy and urbanization have positive link with GDP growth, while GDP growth and CO₂ emissions are negatively related. Cui et al. [44] use multiscale geographically weighted regression (MGWR) to explore the relationship between industrial energy consumption and industrial GDP growth in China. The results of the study show that electricity consumption is significantly linked to GDP and its impact is only increasing over time. Nathaniel and Bekun [45] adopt bound tests to examine the impact of electricity consumption on GDP in Nigeria for the period 1972–2014. The results from cointegration tests suggest that electricity use has a positive impact on economic growth, while urbanization reduces GDP growth rates. Odhiambo [46] assesses the relationship between energy consumption and GDP growth in Botswana over the years 1980–2016. The study applied the ARDL regression method and found that the causality runs from economic growth to energy consumption. The study concludes that GDP growth in Botswana is not driven by energy consumption but by other sources. While extant research offers ample evidence for the energy–GDP nexus for single countries and different regions, this relationship has not been investigated in the context of South Asian countries considering the role of electricity.
3. Methodology and Data

This paper aims to elucidate the energy–growth nexus in South Asian countries during 1990–2018 by considering the relationship between electricity supply, the economic complexity index (ECI), and economic growth. The current territories of Afghanistan, Bangladesh, Bhutan, Maldives, Nepal, India, Pakistan, and Sri Lanka form South Asia. However, we consider only four (Sri Lanka, Bangladesh, India, and Pakistan) due to lacking data for some variables.

Following [6, 40], our empirical model is built mainly on the traditional growth model. To account for productivity, the economic complexity index (ECI) is implemented [13] along with the main independent variable—electricity supply. Thus, the empirical model can be represented as:

\[ Y/L = f(ECI, ES) \] (1)

where ECI is an economic complexity indicator and EC is electricity supply.

Further, we transform the model (3) into logarithmic form and obtain the following:

\[ \ln Y = \alpha + \beta_1 ES + \beta_2 ECI + \epsilon \] (2)

where \( Y \) denotes real GDP per capita (constant 2010 US$). Energy supply is measured as electricity production from oil, gas, and coal sources (% of total), and ECI is an economic complexity index computed using the Standard International Trade Classification.

Following Chen et al. [7] and Yuan et al. [40], Pedroni’s [47] panel cointegration tests, and Dumitrescu and Hurlin [48], panel Granger causality tests are performed. Before testing for cointegration, the order of integration should be analyzed. The time series analysis implies that a long-term cointegrating relationship may be investigated for a set of individually integrated variables of order one, some linear combination of which can be described as stationary [47]. To check for stationarity Im, Pesaran, and Shin’s [49] test is employed as well as Levin, Lin, and Chu’s [50] and Fisher-type tests for panel data. Unlike the LLC test, IPS does not impose the assumption of a common rho for all panels, so that each panel has its own. The test is for dynamic heterogeneous panels and reports the mean of individual unit root statistics, proposing standardized t statistics and following averaged-augmented Dickey–Fuller statistics [49]. This method is widely used in empirical literature to model the energy–GDP nexus as it allows to uncover the directions of causality when using panel data [51–53].

The specification of the test is as follows:

\[ y_{it} = \rho_i y_{i(t-1)} + \sigma_i x_{it} + \epsilon_{it} \] (3)

where \( \rho_i \) and \( \sigma_i \) represent panel-specific means or time trends; \( i = 1, \ldots, N \) for each country; and \( t = 1, \ldots, T \) is the time period. By running an IPS test, we checked the hypothesis of non-stationarity in every individual panel against the alternative, which claims stationarity. Fisher-type tests check for the presence of a unit-root in panel data by combining p-values from an individual unit-root test for each panel, thereby providing overall test results. The null hypotheses of LLC and Fisher-type tests claim non-stationarity, while the alternative assumes that some or at least one panel is stationary.

Because some empirical tests require strongly balanced data, we linearly extrapolate the missing values. Thus, our sample contains 116 observations. Summary statistics, variables description, and a correlation matrix are depicted in Tables 1 and 2. For example, the electricity supply in Bangladesh, India, and Pakistan has steadily increased in the 1990s staying in the range of 50–98% of total energy production. The dynamic of electricity supply in Sri-Lanka has a more vulnerable trend which can be explained by the socio-economic instability caused by civil conflicts, inefficient energy policies, and ineffective reforms. On the other hand, Sri-Lanka demonstrates the steepest trend of GDP per capita among other countries in the sample. The reason for that could be due to the fact that Sri-Lanka has the lowest population density after Pakistan within the observed period.
Table 1. Descriptive statistics.

| Indicator                        | ln Y  | ES                          | ECI                |
|----------------------------------|-------|-----------------------------|--------------------|
| Source                           | WDI   | WDI Atlas MIT               |                    |
| Mean                             | 6.970 | 70.323                      | −0.460             |
| Std. dev                         | 0.558 | 23.323                      | 0.411              |
| Min                               | 5.990 | 0.159                       | −1.229             |
| Max                               | 8.279 | 99.052                      | 0.339              |
| N. of observations               | 116   | 116                         | 116                |

Table 2. Correlation matrix.

| Variables | ln Y | In ES | ECI |
|-----------|------|-------|-----|
| ln Y      | 1.000|       |     |
| ES        | −0.550| 1.000 |     |
| ECI       | 0.356| 0.048 | 1.000|

4. Results

According to Table 3, all variables are stationary after first differencing and significant.

Table 3. Panel unit root test results.

| Variable                  | Form | Method | Statistic | p-Value | Conclusion    |
|---------------------------|------|--------|-----------|---------|---------------|
| ln GDP per capita (ln Y)  | Level| LLC    | 4.009     | 1.000   | Non stationary|
|                           | LLC  | IPS    | 8.739     | 1.000   | Non stationary|
|                           | LLC  | Fisher-ADF | 0.178     | 1.000   | Non stationary|
|                           | LLC  | Fisher-PP | 0.108     | 1.000   | Non stationary|
| First difference          | LLC  | −1.525 | 0.064     |         | Stationary    |
|                           | LLC  | −3.360 | 0.000     |         | Stationary    |
|                           | LLC  | 21.607 | 0.006     |         | Stationary    |
|                           | LLC  | 41.938 | 0.000     |         | Stationary    |
| Electricity supply (ES)   | Level| LLC    | −2.505    | 0.006   | Stationary    |
|                           | LLC  | IPS    | −2.067    | 0.019   | Stationary    |
|                           | LLC  | Fisher-ADF | 16.563    | 0.035   | Stationary    |
|                           | LLC  | Fisher-PP | 18.3683   | 0.019   | Stationary    |
| First difference          | LLC  | −4.558 | 0.000     |         | Stationary    |
|                           | LLC  | −6.557 | 0.000     |         | Stationary    |
|                           | LLC  | 56.761 | 0.000     |         | Stationary    |
|                           | LLC  | 158.494| 0.000     |         | Stationary    |
| ECI                       | Level| LLC    | −3.030    | 0.001   | Stationary    |
|                           | LLC  | IPS    | −1.915    | 0.028   | Stationary    |
|                           | LLC  | Fisher-ADF | 23.427    | 0.003   | Stationary    |
|                           | LLC  | Fisher-PP | 34.969    | 0.000   | Stationary    |
| First difference          | LLC  | 3.194  | 0.000     |         | Stationary    |
|                           | LLC  | −5.176 | 0.000     |         | Stationary    |
|                           | LLC  | 36.034 | 0.000     |         | Stationary    |
|                           | LLC  | 87.2523| 0.000     |         | Stationary    |

After the order of integration was confirmed, the panel cointegration test from [47] was conducted (Table 4). The test rejects the null hypothesis of no cointegration between the variables by employing seven parametric and non-parametric test statistics. The test reports the group statistic that provides averaged results for individual panels and panel statistics, that comprise results along the within-dimension [54]. Since the test is one-tailed, the critical value corresponding to 90 percent confidence interval is approximately equal.
to 1.28. The null hypothesis can be rejected or accepted in favor of the majority of the test statistics. Table 5 confirms the presence of cointegration between electricity supply and economic growth as six out of seven test statistics reject the null hypothesis of no cointegration.

Table 4. Pedroni and Kao panel cointegration tests results.

| Statistics       | Value       |
|------------------|-------------|
| V-stat           | 0.611       |
| Panel rho-stat   | -2.901 ***  |
| Panel PP-stat    | -4.191 ***  |
| Panel ADF-stat   | -4.075 ***  |
| Group rho stat   | -2.192 **   |
| Group PP stat    | -5.252 ***  |
| Group ADF stat   | -4.748 ***  |
| Kao (ADF)        | -3.263 ***  |

Note: *** and ** indicate significance at 1% and 5% levels, respectively.

Table 5. DH Granger non-causality test results.

**Economic Growth Does Not Granger-Cause Electricity Supply**

| Statistics       | Value       |
|------------------|-------------|
| W-bar            | 1.2548      |
| Z-bar            | 0.3603      |
| Z-bar tilde      | 0.198       |

Optimal number of lags (AIC) 1
Lags tested 1 to 7

**Electricity Supply Does Not Granger-Cause Economic Growth**

| Statistics       | Value       |
|------------------|-------------|
| W-bar            | 1.294       |
| Z-bar            | 0.415       |
| Z-bar tilde      | 0.245       |

Optimal number of lags (AIC) 1
Lags tested 1 to 7

Note: While figures in parentheses are p-values.

After we confirmed the long-run relationship between the variables, we proceeded with causality analysis by employing the Granger non-causality test for heterogeneous panel data models. Similar to the IPS test, the DH panel causality test reports the cross-sectional average of the individual Wald statistic [48]. The null hypothesis claims a homogeneous, non-causal relationship for any of the cross-section units of the panel, while the alternative assumes a causal relationship for some cross-sections. Dumitrescu and Hurlin [48] presents the model as depicted below:

\[ y_{i,t} = a_i + \sum_{k=1}^{K} \gamma_{ik} y_{i,t-k} + \sum_{k=1}^{K} \beta_{ik} x_{i,t-k} + \epsilon_{i,t} \]  

(4)

where \( x_{i,t} \) and \( y_{i,t} \) are the observations of two stationary variables for individual \( i \) in period \( t \).

The null hypothesis of the test assumes no causality between the variables and can be either rejected or accepted based on z-bar and z-bar tilde. It is suggested to test the null on the basis of z-bar tilde statistics for a small number of observations (N) and time periods (T) [55]. Lopez and Weber [55] recommend selecting the number of lags based on AIC, BIC, or HQIC information criteria (Table 5).

First, we tested the conservation hypothesis: that economic growth causes electricity supply. Because p-values significantly exceed 10%, we fail to reject the null hypothesis. Similarly, the growth hypothesis cannot be accepted due to large probability values associated
with the z-bar tilde statistic (0.626). Considering individual regressions, our result confirms the growth hypothesis for Pakistan only (Table 6). In general, there is no causal relationship between electricity supply and economic growth in the panel, which includes Sri Lanka, Bangladesh, India, and Pakistan, during 1990–2018. In line with Murry and Nan [56] (1994), Wolde-Rufael [38] and Yoo and Kwak [57], our analysis supports the neutrality hypothesis. Paul and Bhattacharaya [58] contributed to the debate over the conflicting evidence on the relationship between energy and growth in India. The authors applied a cointegration test for the data from 1950 to 1996. The authors observe bi-directional causality between energy and GDP growth. One of the explanations of the mixed effects of energy on GDP growth may come from the sources of energy production. For example, Ohlan [59] finds that renewable energy has a positive impact on GDP growth in India, while there is bidirectional causality between non-renewable energy and GDP growth.

Table 6. Results for DH causality test in a single country.

| Country    | Null Hypothesis                                      | Sources of Causation | Z-Bar Tilde Statistic |
|------------|------------------------------------------------------|----------------------|-----------------------|
| Bangladesh | ES doesn’t Granger-cause GDP                         | ES                   | 1.497 (0.134)         |
|            | GDP doesn’t Granger-cause ES                         | GDP                  | 0.138 (0.890)         |
| India      | ES doesn’t Granger-cause GDP                         | ES                   | −0.391 (0.696)        |
|            | GDP doesn’t Granger-cause ES                         | GDP                  | −0.528 (0.597)        |
| Pakistan   | ES doesn’t Granger-cause GDP                         | ES                   | 1.918 ** (0.055)      |
|            | GDP doesn’t Granger-cause ES                         | GDP                  | −0.081 (0.936)        |
| Sri-Lanka  | ES doesn’t Granger-cause GDP                         | ES                   | −0.406 (0.685)        |
|            | GDP doesn’t Granger-cause ES                         | GDP                  | −0.540 (0.589)        |

Note: ** indicate significance at 5% level. While figures in parentheses are p-values.

5. Conclusions

Since energy efficiency is crucial for economies in the development stage, there are numerous studies that investigate the relationship between energy supply and economic growth. Direction of causality is of particular importance since it drives significant implications in designing and implementing energy policies. While some studies provide evidence in the favor of the growth, conservation, and feedback hypotheses, others confirm that there is no causal relationship between energy supply and economic growth. Although the relationship is widely studied, the evidence is lacking for South Asian countries.

This paper explores the causal link between electricity supply and economic growth in four South-Asian economies during 1990–2018, utilizing Pedroni’s panel cointegration test and Dumitrescu and Hurlin’s panel Granger causality test. Certain policy implications may be driven from the results obtained. Firstly, empirical results confirm a long-term cointegrating relationship between electricity supply and economic growth which suggests the presence of some linking channels between the variables in the long run. Second, our single-country causality analysis provides a mixed and contradicting causal relationship across different economies. For instance, there is no causal link between electricity supply and economic growth in Bangladesh, India, and Sri Lanka, while in Pakistan electricity supply contributes to economic growth. Thus, economic growth can be improved through increasing electricity supply in Pakistan. Lastly, panel cointegration results reveal the neutrality hypothesis, rejecting causal interlinkage between energy supply and economic growth and implying that energy conservation policies may be introduced without a fear of adverse impact on economic growth.

These results have a number of policy implications. For example, governments can introduce the measures to improve energy efficiency in Bangladesh, India, and Sri Lanka without fear of harming economic growth. The results for Pakistan may also imply that fostering green energy generation would lead to a positive effect on economic growth.
via improved electricity production. For example, Luqman et al. [60], using data from Pakistan over the period 1990–2016, found that renewable energy had a positive effect on economic growth. The government may use various policy tools to stimulate adoption of renewable energy such as fiscal incentives, low interest loans, or grants for rural populations to speed up the green energy transformation. In addition, it is important to make shifts towards non-fossil fuel electricity production as it would significantly and positively impact sustainable development. For example, investment in energy infrastructure and adoption of energy-efficient technologies would reduce the strain on the energy sector caused by rising population of the region. Reforms in the energy sector in the South Asian countries would also require the improvement of perceptions of the population on the climate change and renewable energy technologies. In a similar vein, policymakers need to assess the skills gap to address the lack of labor force in the energy sector with required skills in the long-term perspective.

Our study has some shortcomings. First, our sample covers only four South Asian countries due to unavailability of data for other South Asian economies. Moreover, the use of alternative empirical methods requires a strongly balanced dataset for all countries in our sample. Second, splitting causality analysis into short and long term may provide a more robust picture on the effect of electricity supply on economic growth. The prospective studies can extend our analysis in a number of ways. For instance, further investigation is required regarding the channels of the cointegrating relationship between electricity supply and economic growth. Prospective studies should also explore the drivers of electricity consumption in South Asian countries [61]. For example, Saidi et al. [62] shows that information communication technology (ICT) has a significant positive effect on electricity consumption in a sample of 67 nations. In addition, it is important to assess whether other variables may mediate the relationship between electricity consumption and GDP growth in this region [63–65]. Another avenue for future research is the exploration of the drivers of electricity consumption in the South Asia. Finally, it is important to assess the effect of electricity consumption, GDP growth, and other economic variables on CO₂ emissions in South Asian countries.

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