Causal Relationship Between Electricity Production and Macroeconomic Indicators: Cross Countries Analysis

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Today, many developing countries are facing severe shortage of electricity production in their economies which results into a widening gap between electricity production and consumption. This paper employs three-step methodology of Unit Root, Johansen Cointegration, and Vector Error Correction Mechanism to examine whether there exists short-, long-run, uni-, or bi-directional causality among economic growth, electricity production, and inflation for three South Asian economies namely, India, Pakistan, and Bangladesh covering the period 1973-2014. This paper finds the neutrality hypothesis in the short run for India, Pakistan, and Bangladesh. For the long run, the test result indicates that different hypothesis exists for the three countries under the analysis. This implies that policies and strategies for increasing the installed capacity of electricity generation can lead towards prosperous economic growth in the long run.

Keywords: economic growth, electricity production, inflation, causality, cointegration, VECM

Introduction

Electricity is considered as one of the most significant and vital mechanisms for the socioeconomic development of a country. Electricity is essential to carry out production in industries and factories; it is used to lighten our cities and houses. These days, one of the biggest challenges a government can face is the sustainable supply of electricity to the industries and households. Due to swift population growth and industrial development, there has been a tremendous increase in demand for electricity which is significantly greater than its supply. It results into a huge electricity shortage which in turn puts an adverse effect on economic output. Hence, for the smooth running of an economy, continuous supply of power is necessary, especially in developing countries, such as Pakistan.

In Pakistan, electricity production is one of the major constraints in the way of economic growth. Day by day Pakistan is sinking deeper and deeper into this crisis of electricity shortfall, as shown in Figure 1. In Pakistan, the consumption of energy remains higher than its production. This gap between energy needs and supply...
demand/consumption and energy production is increasing rapidly, especially from last 10 years. This issue of insufficiency in energy production should be taken as a serious issue for the smooth running of the economy.

![Graph](image)

**Figure 1.** Gap between energy consumption & energy production in Pakistan. Source: Prepared by author by taking data from World Bank Database.

There has been ample empirical evidence available in literature (Shahbaz & Feridun, 2011; Belke, Dreger, & Haan, 2010; Noor & Siddique, 2010; Apergis & Payne, 2009; Narayan & Singh, 2007; Chima & Freed, 2005; Aqeeq & Butt, 2001) focusing on examining the relationship between electricity consumption and economic growth. In different studies, there exists both short- and long-run causality from energy consumption to economic growth (Apergis & Payne, 2009), and also bidirectional causality between economic growth and energy consumption in the short run, while in the long run there exists unidirectional causality from economic growth to energy consumption (Adnan & Riaz, 2008). The general findings reveal that there is existence of strong relationship between electricity consumption and economic growth (Ferguson, Wilkinson, & Hill, 2000). In addition, it has also been supported in the literature that there is bi- and uni-directional causality between economic growth and electricity consumption (Yang, 2000; Ghosh, 2000; Yoo, 2005).

However, there is little evidence existing on examining the causal relationship between electricity production and economic growth. There can be the existence of direction of causality running from electricity production to economic growth and/or from economic growth to electricity production. If causality runs from electricity production to economic growth, then increasing electricity production could lead to advancement in economic output. And if causality runs from economic growth to electricity production then policies for enhancing economic growth may be implemented with favorable effects on electricity production. This issue of causality which is crucial for policy makers therefore suggests that there is need for more in-depth investigation of this causal relationship.

Zeeshan (2013) indicates that if, for example, uni-directional causality runs from electricity production to economic growth then mitigating electricity production would lead to fall in economic output. It is called as growth hypothesis. Whereas, reducing the electricity production would have little or no adverse effect on
economic growth if the uni-directional causality is from economic growth to electricity production, called as conservation hypothesis. On the other hand, there can be the existence of bi-directional causal relationship between electricity production and economic growth; it’s called as feedback hypothesis. Now days, the electricity infrastructure is becoming an essential part of the economy. It is widely recognized that electricity enhances the productivity of various factors of production, mainly the two: capital and labor. Increase in electricity production would result in boosting the factors’ productivity that leads to rapid economic growth, which sequentially results in developing appropriate electricity production policies to improve the electricity generation mechanism.

Lastly, neutrality hypothesis considers no causality between the two variables. That is, there is no relationship between electricity production and economic growth. It would show that policies for increasing electricity production do not affect economic growth and vice-versa. Yu and Jin (1992) supported neutrality hypothesis for energy consumption while investigating the long-run stationary relationship among energy consumption, industrial output, and employment in USA over the period 1974-1990. Another study by Nung, Hwang, and Yang (2008) reveals that there is no evidence indicating energy consumption leads to economic growth in different income groups.

Sources that contribute to the production of electricity in Pakistan, along with their shares in 2012 are shown in Figure 2. The contribution of coal sector is too low, although Pakistan is rich in coal resources. If, more investment is done in this sector it would help in producing more electricity at cheaper rates as compared to other resources, especially oil.

| Share of Sources in Electricity Production in 2012 |
|--------------------------------------------------|
| Oil: 35.0%                                       |
| Gas: 29.0%                                       |
| Hydle, Nuclear, & Import: 35.7%                  |
| Coal: 0.1%                                       |

*Figure 2. Share of sources in electricity production in 2012. Source: Prepared by author by taking data from Economic Survey of Pakistan (2012).*

Compared with Pakistan, its neighboring country, India, produces 71.0% of electricity by using its coal resources (see Table 1). By consuming coal for electricity generation, Pakistan can save its gas resources for domestic and commercial use to overcome the gas shortages which would help in the growth of small scale production units that would contribute in the growth of the economy too.
It is obvious from the above discussion that the causal relationship between energy consumption and economic growth has been investigated by various studies but the issue of direction of causation remains unresolved. As discussed earlier, there are four hypotheses supported by several studies pertaining to direction of causality between energy consumption and growth. Growth hypothesis is backed by Soytas and Sari (2006) and Stern (2000). Studies by Sari, Ewing, and Soytas (2008), Thoma (2004), and J. Kraft and A. Kraft (1978) support the conservation hypothesis. Thirdly, the presence of bidirectional causality (feedback hypothesis) is accepted by Mahadevan and Asafu-Adjeaye (2007) and Lee (2006). Finally, neutrality hypothesis is supported by Payne (2009a), Narayan and Prasad (2008), Chontanawat, Hunt, and Pierse (2006; 2008), Soytas, Sari, and Ewing (2007), and Akraca and Long (1980).

Table 1
Comparison of Electricity Production by Sectors

|        | 2012 |       | 2012 |       | 2012 |       |
|--------|------|-------|------|-------|------|-------|
|        | Gas  | Oil   | Coal | Hydle, nuclear or import | Hydle, nuclear or import |
| India  | 9.2% | 0.8%  | 71.0%| 19.0% | 19.0% | 19.0% |
| Bangladesh | 73.0% | 20.4% | 3.4% | 3.2% | 3.2% |
| Pakistan | 29.0% | 35.0% | 0.1% | 35.7% | 35.7% |

Source: Economic Survey of Pakistan (2012).

Recently, an attempt (Zeeshan, 2013) has been made to analyze the causality between electricity production and economic growth using private business investment as a proxy for economic growth. The rationale of this paper is that it has made a comparative analysis of the causal relationship between electricity production and economic growth in three major South Asian economies namely Pakistan, Bangladesh, and India. In this paper, we use GDP as an indicator for economic growth. The justification of using GDP is that it is the most appropriate indicator of measuring well-being and prosperity of a nation. Overtime changes in an economy can be captured by GDP. Paul Samuelson, Nobel Laureate, once termed GDP as “truly among the great inventions of the 20th century, a beacon that helps policymakers steer the economy toward key economic objectives”.

Furthermore, considering Pakistan’s current situation, rapid inflation in the country is also affecting electricity production. Following Masih and Masih (1997), Hondroyiannis, Lolos, Papapetrou (2002), and Levent (2007) we also incorporate effect of prices on the relationship between electricity production and economic growth. Hondroyiannis et al. (2002) pointed out the addition of prices into this relationship because prices are used as a proxy to represent efficiency of the economy. This inclusion will also reveal the effect of prices on electricity production specifically for the developing country like Pakistan. Therefore, we have included prices in the model to look at the role of prices in affecting the electricity production. This inclusion will provide an additional channel for policy makers to design the appropriate energy policies for the country.

This paper aims to examine the causal relationship between electricity production, economic growth, and inflation in Pakistan, Bangladesh, and India. A three-step methodology is used to carry out the empirical investigation. Firstly, unit root properties of the variables are checked by employing Augmented Dickey-Fuller (1979) test and Phillips-Perron (1988) test. Secondly, if all the variables are found to be integrated of the same order then Johansen cointegration technique (Johansen & Juselius, 1990) is used to check the long-run relationship. Finally, Vector Error Correction is used to estimate the short- and long-run causality among the variables. The rest of the paper is organized as follows: section 2 covers the literature review on the study;
section 3 describes data and methodology; section 4 explains empirical result; section 5 is conclusion; and lastly section 6 explains few policy implications of the study.

**Literature Review**

As mentioned above, there is limited amount of research which focuses on the causal relationship between electricity production and economic growth. This section provides an overview of empirical studies conducted on the existence of causal relationship between electricity consumption/production and economic growth and some other macroeconomic variables. The table in Appendix highlights the findings of some of those studies.

Chima and Freed (2005) contribute from their study that energy conservation policies will not harm the U.S. economy and suggest that the causation goes from energy to the components of GDP and also from GDP to energy consumption for the period from 1949 to 2003. For another case of USA, Payne (2009b) concludes the unidirectional causality from energy consumption to employment analyzing the period from 1976 to 2006.

Yoo and Kim (2006) use the time series data for the period 1971-2002 in case of Indonesia. They explore that uni-directional causality run from economic growth to electricity generation by applying the granger causality test. Morimoto and Hope (2004) identify that electricity supply has a significant impact on a change in real GDP over the period of 1960-1998 in Sri Lanka. It indicates that bi-variate relationship prevails among the variables.

Apergis and Payne (2009) investigated for causality from energy consumption to economic growth for six Central American countries, namely, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama over a period of 1980-2004. The results show that causality exists between the variables for both the short- and the long-run. Similarly, S. T. Chen, Kuo, and C. C. Chen (2007) tested for the relationship between GDP and electricity consumption in 10 newly industrializing and developing Asian countries for 1971-2001. The result for this study suggests that there is a uni-directional short-run causality running from economic growth to electricity consumption and a bi-directional long-run causality between electricity consumption and economic growth for those selected countries. Huang, Hwangc, and Yang (2008) report that there is no evidence indicating that energy consumption leads economic growth in any of the four income groups. Analyzing the 82 countries from 1972 to 2002 based on the income levels defined by the World Bank as: low income group, lower middle-income group, upper middle income group, and high income group.

Saatcioglu and Korap (2007) study the relationships between energy consumption, real income, and prices for 1968-2005 in Turkey. They conclude that causal link exists towards the change in energy consumption through the real income growth. Narayan and Singh (2007) consider the case of Fiji Islands for 1971-2002. They come up with the result showing unidirectional causality running from electricity consumption to GDP in the long run and a bidirectional causality running from GDP to labor force in the short run.

In case of India, Shyamal and Bhattacharya (2004) applied different methodologies for the period from 1950 to 1996 and came up with the existance of bi-directional causality between energy consumption and economic growth. Mallick (2009) examines the linkage between energy fuels and economic growth or vice versa. In the Indian context this study observes a conflicting result, comparing with the previous studies. The study suggests that reducing oil and natural gas consumption would lead to achieving higher rate of economic growth in the economy. Sarker and Alam (2010) studying the case of Bangladesh over the period 1973-2006 employ the unidirectional causality existing between electricity generation and economic growth. Whereas, in
the short run the relationship originates from electricity generation to economic growth. Therefore, the guidelines and tactics for escalating electricity generation can be helpful for improving the economic growth in the country. Masuduzzaman (2012) exploring the period from 1981 to 2011 for economic growth, electricity consumption, and investment in Bangladesh indicates the existence of unidirectional relationship from electricity consumption to economic growth, electricity consumption to investment and investment to economic. This shows that higher electricity consumption and investment in Bangladesh would lift up the economic growth.

Shahbaz, Saleheen, and Tahir (2012) study the dynamic link between energy consumption, economic growth, financial development, and trade in China for the period 1971-2011. They find the unidirectional causal relationship from energy consumption to economic growth. Further they come up with the result that financial development and energy consumption granger cause each other and also there exists bidirectional causality between trade and energy consumption. They also find that there is a feedback relation between financial development and international trade and bidirectional causality between capital and energy consumption, financial development and economic growth and, international trade and economic growth. Working on the empirical evidence from Pakistan, Shahbaz and Feridun (2011) examine that economic growth leads to electricity consumption and not vice versa for the period of 1971-2008.

Adnan and Riaz (2008) find the bidirectional causality between economic growth and energy consumption in the short run. But in the long run they find unidirectional causality from economic growth to energy consumption for the period of 1971-2007 in Pakistan. Siddiqui (2004) considering the case of Pakistan for 1970-2003 finds that energy expansion is expected to lead to higher economic growth and its shortage may retard the growth process. Aqeel and Butt (2001) investigate the relationship between energy consumption and economic growth in Pakistan for the period of 1956 to 1996. They find that electricity consumption leads to economic growth without feedback effect. Moreover, this study finds that energy consumption also directly causes employment.

From the above discussion on literature review it is evident that the relationship between energy production and economic growth is not conventional in the literature, and the path of causation is still unknown. In this paper, we have tried to answer the following questions:

- Does electricity production cause economic growth or vice versa?
- Does inflation cause economic growth or vice versa?
- Does inflation cause electricity production or vice versa?

Data and Methodology

Data

The estimation is performed on the annual data for Pakistan, Bangladesh, and India on relevant variables i.e., electricity production, GDP, and Inflation. The time under consideration ranges from 1973-2014. Electricity production is measured in Kilowatt Hours. To measure economic growth, real GDP is used which is at the constant prices of 2005. Inflation is measured using GDP Deflator. Data for these variables are taken from World Bank Database.

Zeeshan (2013) used private business investment as a proxy for economic development indicator. Whereas, in this study, real GDP has been used to measure economic growth. We argue that real GDP is a better proxy for economic growth because a country’s total electricity production depends upon the quantity of goods and
services produced within the country (Yoo & Kim, 2006). All the variables have been used in log-linear form to get the robust results as compared to linear specification (Nasir, Salman, & Arif, 2008; Noor & Siddiqi, 2010; Shahbaz & Lean, 2012a; 2012b).

**Methodology**

Firstly, to check the order of integration of the variables Augmented Dickey-Fuller (1979) and Phillips-Perron (1988) test is used. Unit root test is applied to test whether the stochastic process is stationary or not. Any series is said to be stationary if it fulfills the following conditions:

- Mean of the series should be finite, constant, and independent of time.
- Variance of series needs to be finite and constant over time.
- Covariance between any two values of the series should be finite, constant, and independent of time.

Augmented Dicky-Fuller (ADF) and Phillips-Perron (PP) test are applied for testing the stationarity of the data. ADF test is same as Dicky-Fuller test (DF) test. However, this includes a large number of lagged values of dependent variable so that the problem of autocorrelation is removed. The null hypothesis is taken as non-stationary whereas the alternative hypothesis is taken as stationary. A series is said to be stationary if the null hypothesis is rejected. ADF test is one tail left hand tail test. So the critical values given by t-test are called Mackinnon critical values. If the absolute value of calculated t-test is greater than the absolute value of critical t-test then we will reject our null hypothesis (H0). In ADF we have the following model, random walk with drift and time trend. \( \Delta Y_t \) can be any variable where \( \epsilon_t \) is a pure white noise error term and

\[
\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \sum_{i=1}^{m} \alpha_i \Delta Y_{t-1} + \epsilon_t
\]  

(1)

where

\[
\Delta Y_{t-1} = (Y_{t-1} - Y_{t-2}), \Delta Y_{t-2} = (Y_{t-2} - Y_{t-3}), \text{etc}
\]  

(2)

Secondly, to find out long-run relationship among the variables cointegration shows the existence of long run or equilibrium relationship among variables. The concept of co-integration was developed by Granger (1981). The variables are said to be cointegrated if their linear combination has a low order of integration i.e., Linear combination of I (1) and I (0). If all the variables are integrated of the same order, then there exists a unique long-run relationship among the variables (Johansen, 1991; Johansen & Juselius, 1990). If variables in the model are found to be integrated of different order then Johansen cointegration technique is not applicable. This problem is solved by Autoregressive Distributed Lags (ARDL) models. ARDL models help in holding the long-run relationship and it also offers robust results if the variables are of different order of integration (M. H. Pesaran & B. Pesaran, 1997).

Statistically, a long-run relationship means that the variables move together for a long period and if any short-term disturbances occur in this long period that will be corrected. To explore the long-run relationship among the variable we use vector autoregressive (VAR) model which was introduced by Johansen (1988). VAR shows how the variables are interrelated over time. In this approach no single variable can be considered as dependent variable. Eq. 3 is the general form of cointegrating equation.

\[
\Delta Z_t = B(L) \Delta Z_{t-1} - \Pi Z_{t-1} + \epsilon_t
\]  

(3)

where \( \Delta = 1-L \) is the first difference operator, and

\[
B(L) = \sum_{i=1}^{p} B_i L^{i+1} , \text{ } B_i = \sum_{j=i+1}^{p} A_j , \text{ } p=1 \text{ }, \text{ } \Pi = I - A,
\]
In the above equation, $\Pi = (I - A)$ represents the long-run cointegrating matrix which has equilibrium (error) correction terms in it. $\beta'Z_{t-1}$ is a stationary variable where $B(L)$ is the VAR coefficient. In Equation (3), Johansen cointegration approach is used for testing the co-integration between variables where the coefficients in this equation are estimated by using maximum likelihood method. Johansen procedures of co-integration introduced two likelihood ratio tests i.e. trace test and maximum eigen value test. The benefit of using Johansen cointegration test is that it can estimate more than one cointegration relationship.

Finally, long- and short-run causality among the variables will be checked by employing Vector Error Correction Mechanism (VECM). In VECM, the significant coefficient of error correction term (ECT) indicates the presence of long-run causality form explanatory variable to the dependent variable. While the significance of the coefficients of lagged value of the explanatory variables identifies the existence of short-run causality form independent variable to the dependent variable. In the following equations:

- GDP, is natural logarithm of real GDP (base year = 2005);
- EP, is natural logarithm of electricity production measured in Kilowatt Hours;
- INF, is natural logarithm of GDP Deflator.

\[
\Delta EP_t = \alpha_i + \sum_{i=1}^{n} \beta_{2i} \Delta EP_{t-i} + \sum_{i=1}^{n} \gamma_{2i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \delta_{2i} \Delta INF_{t-i} + \sum_{i=1}^{r} \lambda_{2i} ECT_{r,t-1} + \epsilon_{2t} \tag{4}
\]

\[
\Delta GDP_t = \alpha_i + \sum_{i=1}^{n} \beta_{1i} \Delta EP_{t-i} + \sum_{i=1}^{n} \gamma_{1i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \delta_{1i} \Delta INF_{t-i} + \sum_{i=1}^{r} \lambda_{1i} ECT_{r,t-1} + \epsilon_{1t} \tag{5}
\]

\[
\Delta INF_t = \alpha_i + \sum_{i=1}^{n} \beta_{3i} \Delta EP_{t-i} + \sum_{i=1}^{n} \gamma_{3i} \Delta GDP_{t-i} + \sum_{i=1}^{n} \delta_{3i} \Delta INF_{t-i} + \sum_{i=1}^{r} \lambda_{3i} ECT_{r,t-1} + \epsilon_{3t} \tag{6}
\]

**Empirical Results**

Results of ADF test and Phillips-Perron test of unit root are reported in Table 2. Presence of unit root in a series represents non-stationarity. The null hypothesis of non-stationarity of variables is tested against the alternative hypothesis of stationarity.

Since, at level of the variables, $p$-values are greater than conventional 5% level of significance. Therefore, it leads to the failure to reject null hypothesis of non-stationarity at level form. Hence, there is existence of a unit root in all the variables as proved by both ADF and PP test. Whereas, at first differences, all the variables become stationary on the basis of rejection of null hypothesis at 1% level of significance as indicated by the $p$-values. Hence, EP, GDP, and INF are proved to be integrated of order one i.e. I (1) for Pakistan, Bangladesh, and India.

Co-integration relationship is investigated by using Johansen technique. Trace and maximum eigen value statistics are calculated to check cointegrating relationship among the variables. The null hypothesis of no co-integration is tested against the alternative hypothesis of one co-integrating vector. Trace test is used to check whether there exists co-integration between variables or not. The results of the test are reported in Table 3. The results indicate that co-integration relationship among electricity production, GDP, and inflation exists. To find out the exact number of co-integrating vectors we use maximum eigen value test. The results of $\lambda_{\text{max}}$ test are also given in Table 3.
The results of the Johansen test show that the null hypothesis of no cointegration is rejected at 5% significance level. However, the null hypothesis of one co-integration cannot be rejected. The existence of co-integration relationship among electricity production, GDP, and inflation suggests that there is long-run relationship between the three series in all the three countries under consideration and the residuals obtained from the co-integrating vectors are stationary at their level i.e. I(0). For Johansen Cointegration test 1 lags are selected according to SIC and AIC.

Table 2

Unit Root Test

| Variables | ADF | PP |
|-----------|-----|----|
|           | Level | 1st difference | Level | 1st difference |
|           | t-stats | p-value | t-stats | p-value | t-stats | p-value | t-stats | p-value |
| GDP       | -0.95  | 0.77   | -4.61  | 0.003  | 1.59   | 1.00   | -4.93  | 0.001  |
| EP        | 1.24   | 0.99   | -5.03  | 0.001  | -0.422 | 0.982  | -5.09  | 0.001  |
| INF       | -3.43  | 0.06   | -4.13  | 0.01   | -3.01  | 0.14   | -4.13  | 0.01   |

Table 3

Result of Johansen Cointegration Test

| Null hypothesis | Alternate hypothesis | Critical values 5% | P-values |
|-----------------|----------------------|--------------------|---------|
|                | Eigenvectors | λ_{max} rank value | P-values |
| H₀: r = 0       | 0.471656     | 41.24684           | 35.19275 | 0.0099 |
| H₁: r > 0      | 0.471656     | 41.24684           | 35.19275 | 0.0099 |
| H₀: r ≤ 1      | 0.220734     | 17.00257           | 20.26184 | 0.1324 |
| H₁: r > 1      | 0.220734     | 17.00257           | 20.26184 | 0.1324 |
| H₀: r ≤ 2      | 0.179657     | 7.525254           | 9.164546 | 0.1013 |
| H₁: r > 2      | 0.179657     | 7.525254           | 9.164546 | 0.1013 |

Notes. 1%, 5%, and 10% critical values are -4.219, -3.533, and -3.198 respectively. For ADF, lags are chosen according to Schwarz Information Criterion. For PP test bandwidth is selected according to Newey-West using Bartlett kernel.
### CROSS COUNTRIES ANALYSIS

#### Table 3 continued

| Bangladesh | Null hypothesis | Alternate hypothesis | Critical values 5% | P-values |
|------------|----------------|---------------------|--------------------|---------|
|            |                |                     | Eigenvalues | $\lambda_{max}$ rank value |                |
| $H_0: r = 0$ | $H_1: r > 0$   | 0.574389             | 46.46126    | 29.79707 | 0.0003 |
| $H_0: r \leq 1$ | $H_1: r > 1$  | 0.261151             | 14.00053    | 15.49471 | 0.0829 |
| $H_0: r \leq 2$ | $H_1: r > 2$  | 0.063657             | 2.499373    | 3.841466 | 0.1139 |

| India | Null hypothesis | Alternate hypothesis | Critical values 5% | P-values |
|-------|----------------|---------------------|--------------------|---------|
|       |                |                     | Eigenvalues | $\lambda_{max}$ rank value |                |
| $H_0: r = 0$ | $H_1: r > 0$   | 0.490245             | 38.62878    | 29.79707 | 0.0037 |
| $H_0: r \leq 1$ | $H_1: r > 1$  | 0.243678             | 13.02346    | 15.49471 | 0.1140 |
| $H_0: r \leq 2$ | $H_1: r > 2$  | 0.061465             | 2.410533    | 3.841466 | 0.1205 |

### Table 4

**Results of VECM**

| Pakistan | \(\Delta EP\) | \(\Delta GDP\) | \(\Delta INF\) |
|----------|----------------|----------------|----------------|
| ECT(-1)  | -0.052485  [-2.75252] | -0.028124  [-3.07794] | -0.046591  [-2.72955] |
| \(\Delta EP\) | [-2.65821] |                   |                |
| \(\Delta GDP\) |                   | [-2.65821] |                |
| \(\Delta INF\) |                   |                   | [-2.65821] |
| Bangladesh | \(\Delta EP\) | \(\Delta GDP\) | \(\Delta INF\) |
| ECT(-1)  | -0.000252  [-0.10044] | 0.004529  [6.23396] | -0.016268  [-3.91586] |
| \(\Delta EP\) |                   |                   | [-3.91586] |
| \(\Delta GDP\) |                   | [-3.91586] |                |
| \(\Delta INF\) |                   |                   | [-3.91586] |
| India | \(\Delta EP\) | \(\Delta GDP\) | \(\Delta INF\) |
| ECT(-1)  | -0.465373  [-5.01789] | 0.085661  [0.95258] | 0.255800  [1.91982] |
| \(\Delta EP\) |                   |                   | [1.91982] |
| \(\Delta GDP\) |                   | [-1.91982] |                |
| \(\Delta INF\) |                   |                   | [-1.91982] |
Finally, vector error correction model (VECM) is estimated to examine the causal relationship among electricity production, GDP, and inflation in Pakistan. The significant \( t \)-values of the error correction term indicate the existence of long-run causality running from explanatory variable to the dependent variable. These are the coefficients of the speed of adjustment which shows how quickly deviation from equilibrium feedback into the system. The significant \( t \)-values of the lagged independent variables show presence of short-run causality from explanatory variable to the dependent variable. The result of VECM is reported in Table 4 which shows only the significant values of the lagged independent variables.

Results in Table 4 indicate that in Pakistan there is existence of bi-directional long-run causality from GDP to electricity production and from electricity production to GDP, hence, confirming feedback hypothesis in long run. There is also evidence of bi-directional long- and short-run causality between electricity production and inflation. We have not found short-run causality in either way between electricity production and GDP, therefore proving neutrality hypothesis to hold in the short run.

It is seen that inflation negatively causes electricity production in the short run. It is due to the fact that price inflation in Pakistan is mainly due to higher oil prices and country imports $14.5 billion worth of oil each year (Pakistan Economic Survey, 2012-2013). This in turn raises cost of production of electricity production companies which further leads to fall in electricity output. Hence, higher inflation causes less electricity production. It is also clear from the results that GDP also causes electricity production in the short run.

For the case of Bangladesh there is evidence of growth hypothesis i.e. uni-directional long-run causality relationship is there from electricity production to GDP. However, there is also existence of uni-directional causality from electricity production to inflation. On the other hand, we have found neutrality hypothesis in the short run. There is also bi-directional short-run causality between GDP and inflation. Lastly, there is uni-direction long-run causality from GDP to electricity production in India. Hence, India is having existence of conservation hypothesis in the long run. Also, bi-direction long-run causality holds between inflation and electricity production. Again for India there is evidence of neutrality hypothesis in the short run.

Conclusion

Various empirical literatures have focused on the causal relationship between electricity/energy consumption and economic growth whereas very little attention has been paid to analyze the causality between electricity production and economic growth. In this study we have mainly focused on investigating the causal relationship between electricity production and economic growth (measured by real GDP) for Pakistan, India, and Bangladesh with an addition of prices in the model. Impact of prices is crucial for the electricity-GDP relationship because keeping in view the rising inflation in Pakistan, it is vital to analyze its effect on electricity production.

Data for electricity production, GDP, and inflation are taken from World Bank database from the period 1973 to 2012. Unit Root, Cointegration, and VECM have been applied to check order of integration, long-run relationship, and short- and long-run causality among the variables respectively. Unit Root test (ADF and PP) results specify all the variables of integrated of order one i.e. I (1) which means variables are differenced stationary. Johansen Cointegration identifies one cointegrating vector among the variables which proves long-run relationship of the variables. Finally, VECM gives the idea about short- and long run causality. Bi-directional long-run causality is present between GDP and electricity production in Pakistan which proves the existence of feedback hypothesis. Also, there is confirmation of bi-direction long-run causality between
electricity production and inflation. However, we have found no causality to hold in the short run in either direction therefore proving neutrality hypothesis. For Bangladesh, in the long run there is proof of growth hypothesis whereas neutrality hypothesis holds in the short run. India proves to have conservation hypothesis in the long run and neutrality hypothesis in the short run.

**Policy Implications**

Keeping in view the results, it is suggested that economic growth can be enhanced by focusing on cost effective techniques of producing electricity. There is an immense need to create the huge reservoirs of water by building dams, to produce more and more Mega Watts of electricity because more the production of electricity more would be the economic growth in a country. Also the electricity generation through alternate and cheaper resources should be utilized efficiently by using nuclear energy, and coal reserves. So, with continuous and uninterrupted power supply, as in developed countries, the agricultural as well as industrial sector would flourish which would generate higher income and revenue at country level. This positive situation could help in rapid and sustainable economic development of Pakistan.

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### Appendix

| Sr.# | Author(s) & year | Country | Time Period | Methodology | Major findings |
|------|------------------|---------|-------------|-------------|---------------|
| 1    | Christopher M. Chima, Rodney Freed (2005) | USA     | 1949-2003   | Multiple Model Estimation | Causation goes both ways: from energy to the components of GDP, and from GDP to energy consumption. |
| 2    | James E. Payne (2009) | USA     | 1976-2006   | Toda-Yamamoto Test | Unidirectional causality from energy consumption to employment. |
| 3    | Seung-Hoon Yoo, Yeonbae Kim (2006) | Indonesia | 1971-2002   | Granger-Causality Test | Uni-directional causality run b/w economic growth to electricity generation. |
| 4    | Risako Morimoto, Chris Hope (2004) | Sri Lanka | 1960-1998   | Granger Causality Test | Bi-variate relationship electricity supply have a significant impact on a change in Real GDP. |
| 5    | Paresh Kumar Narayan, Baljeet Singh (2006) | Fiji Islands | 1971-2002 | ARDL Bounds test, Granger causality F-test | Unidirectional Causality running from electricity. Consumption to GDP in the long run and a bidirectional causality running from GDP to labor force in the short run. |
| 6    | Shahbaz Muhammad, Khan Salebeen and Iqbal Tahir Mohammad (2012) | China | 1971-2011 | ARDL bounds Test, Structural Break Test, Granger Causality | Unidirectional causal relationship from energy consumption to economic growth. Financial development and energy consumption granger cause each other. Bidirectional causality between trade and energy consumption. Feedback relation between financial development and international trade. Bidirectional causality between capital and energy consumption, financial development and economic growth and, international trade and economic growth. |
| 7    | Cem Saatcioglu, Levent Korap (2007) | Turkey | 1968-2005 | Granger Causality Tests | Causal link exists towards the change in energy consumption through the real income growth. |
| 8    | Nicholas Apergis, James E. Payne (2009) | Six Central American Countries | 1980-2004 | Panel Vector Error Correction Model | Both short- and long-run causality from energy consumption to economic growth. |
|   | Authors                                          | Countries/Period            | Methodology                                    | Findings                                                                 |
|---|-------------------------------------------------|----------------------------|-----------------------------------------------|--------------------------------------------------------------------------|
| 9 | Sheng-Tung Chen, Hsiao-I Kuo, Chi-Chung Chen    | 10 newly Industrializing and Developing Asian Countries 1971-2001 | Vector Error Correction Model                 | Uni-directional short-run causality running from economic growth to electricity consumption and a bi-directional long-run causality between electricity consumption and economic growth. |
| 10| Bwo-Nung Huang, M. J. Hwang, C. W. Yang         | 82 Countries 1972-2002     | GMM-SYS Approach                              | No evidence indicating that energy consumption leads to economic growth in any of the four income groups. |
| 11| Ansgar Belke, Christian Dreger, and Frauke de Haan | 25 OECD Countries 1981-2007 | Granger Causality                             | Bi-directional causal relationship between energy consumption and economic growth. |

**Section III: Studies on Pakistan**

|   | Authors                                          | Countries/Period            | Methodology                                    | Findings                                                                 |
|---|-------------------------------------------------|----------------------------|-----------------------------------------------|--------------------------------------------------------------------------|
| 12| Qazi Muhammad Adnan Hye and Sana Riaz           | Pakistan 1971-2007          | Granger Causality Test                        | Bidirectional causality between economic growth and energy consumption in the short run; in the long run we find unidirectional causality from economic growth to energy consumption. |
| 13| Anjum Aqeel, Mohammad Sabihuddin Butt           | Pakistan 1956-1996          | Granger Causality, Hsiao’s Version of Granger Causality | (a) Economic growth causes total energy consumption. (b) Electricity consumption leads to economic growth without feedback. (c) Energy consumption also directly causes employment. |
| 14| Rehana Siddiqui                                 | Pakistan 1970-2003          | Hsiao’s Granger Causality Test                | Energy expansion is expected to lead to higher growth and its shortage may retard the growth process. |
| 15| Muhammad Shahbaz, Mete Feridun                  | Pakistan 1971-2008          | ARDL bounds Test, Granger Causality           | Economic growth leads to electricity consumption and not vice versa. |
| 16| Zeeshan                                         | Pakistan 1975-2010          | Bound Test Co-Integration,                    | Bound test: unique long-run relationship between the variables exists. |