Economics and Business Letters
2(1), 21-32, 2013

Electricity consumption and economic growth: evidence from Pakistan

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Received: 19 April 2012
Revised: 5 February 2013
Accepted: 6 February 2013

Abstract

The prime objective of this study is to examine the long run relationship between real GDP per capita and electricity consumption for Pakistan over the period 1971 to 2008. The results reveal that there is unidirectional causality from electricity consumption to real GDP per capita. The findings of the study also show that there is a long run relationship between real GDP per capita and electricity consumption. The unidirectional causality running from electricity consumption to economic growth indicates that electricity is a limiting factor to economic growth and hence shocks to electricity supply will have a negative impact on economic growth. The implication emerging from this study is that for an electricity-deficient country like Pakistan, where the electricity sector operates at bare capacity margin, there is a need for planning and investment in infrastructure development to fulfill increased electricity demand.

Keywords: electricity consumption, economic growth, causal relationship, cointegration

JEL Classification Codes: Q43, C52

1. Introduction

In the globalizing world, rapidly increasing demand for electricity and dependency of countries on electricity indicate that electricity will be one of the biggest problems in the world in the next century. Macroeconomic growth theories in the economic literature focus on labor and capital

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Citation: A.Y. Javid, M. Javid and Z.A. Awan (2013) Electricity consumption and economic growth: evidence from Pakistan, *Economics and Business Letters*, 2(1), 21-32.

Oviedo University Press
ISSN: 2254-4380

and do not attach sufficient relevance to the role of energy, which is important for economic growth and production (Stern and Cleveland, 2004). It is seen that electricity is the highest quality energy component and its share in energy consumption increases rapidly. Electricity consumption is considered as an indicator of socio-economic development along with its role in the production function. Recent rises in energy prices, shrinking existing resources, and the search for alternative sources of energy and energy conservation technologies have brought into focus the issue of causality between energy use and economic growth. Various studies have been applied to determining the nature of the casual relationship between energy consumption and economic growth. Energy is an important element for production and economic growth. This study analyzes electricity consumption and its relationship with economic growth in Pakistan.

Pakistan has recently been going through one of its worst electricity crises, with a shortfall of more than 5000 MW (Economic Survey of Pakistan, 2011). The resulting power cuts in the form of load shedding not only affect the normal life of the people of the country but also badly damages the commerce, industry, and agriculture sectors. This ultimately has negative effects on the economic growth of the country which has severe consequences for unemployment and the socioeconomic condition of the country. The electricity crisis is not a recent phenomenon in Pakistan, but this power crisis in particular is the result of a power policy adopted by the government in 1994which has opened electricity generation to the private sector. With the introduction of the private sector into power generation, the fuel mix in electricity generation has changed in favor of imported furnace oil. Until 2002, this policy worked reasonably well because the oil price in international market remained low. After 2002, the international price of fuel started rising and so did the cost of electricity generation. The cost of electricity generation, however, increased drastically in 2007-08 with an unprecedented surge in international fuel prices. In response to the higher cost of electricity generation, the government has been raising the price of electricity continuously over the last four years.

With this background, it is important for policy makers to understand the relationship between electricity consumption and economic growth in order to effectively design power policy. The general conclusion from previous studies regarding Pakistan's electricity consumption and economic growth nexus is that there is no consensus on the direction of causality between electricity consumption and economic growth.

The main objective of this study is to analyze the role of electricity in the economic development process of the country. The study examines the causal relationship between electricity consumption and real GDP and the long run relationship between electricity consumption and real GDP. The dynamic relationship and forecasting between electricity consumption and real GDP is also investigated.

The study differs from earlier studies in two dimensions. First, earlier studies examine the issue of causality for Pakistan but ignore the impact of changes in other sources of economic growth. The study intends to analyze the role of electricity in economic growth while controlling for changes in primary factors of production and other sources of growth. Second, earlier studies examine the impact of total energy use on economic growth, while this study will only focus on electricity. To our best of knowledge no study is available which analyzes the causal relationship between electricity demand and economic growth. To test the causal relationship between electricity demand and real GDP growth, the Dolado–Lutkepohl test using Vector Autoregression (VAR) in levels and the standard Granger causality test are used.

The study is organized as follows. The literature review is presented in section 2. Section 3 discusses the data and methodology, the empirical results are presented in section 4 and last section offers conclusions.

2. Literature review

The issue of demand for energy is a well-researched area both in the developing and developed economies. This section briefly reviews the previous empirical literature in this area. Energy is an essential input for the continuity of the production process and electricity is the highest quality element, with its share in energy consumption increasing rapidly. A study by the International Energy Agency (IEA) which included energy in the production functions of some of the developing countries for the 1981–2000 period concluded that energy played a very major role in economic growth compared to other variables in the production function in the countries which are at intermediate stages of economic development (IEA, 2004). An increase in energy use is expected to lead to higher growth and its deficiency may cause a slowdown in the growth process, and economic growth may also affect the demand for energy significantly (Siddiqui, 2004).

The evidence for Pakistan also reveals that energy consumption affects economic growth significantly and there is bi directional causality between economic growth and consumption of petroleum products and no causal relationship between natural gas consumption and economic growth (Aqeel and Butt, 2001).The evidence at the sectoral level shows that the use of energy affects the growth of the manufacturing sector in Pakistan, However the substitution possibilities are limited among energy and non-energy inputs and between electricity and gas for the period 1972-93 (Mahmud, 2000).

Many studies have examined the causal relationship between energy consumption and economic growth. Electricity consumption is of special interest, as it is not only related to economic wealth but is also an indicator of socioeconomic development. For instance, Ferguson et al. (2000) finds that there is a strong correlation between electricity use and economic development in a study covering over 100 countries. They concluded that there is a strong correlation between electricity use and wealth creation. Since correlation analysis does not involve causality, recent studies (for example Ghosh, 2002; Shiu and Lam, 2004; Moritomo and Hope, 2004; Jumbe, 2004; Wolde-Rufael, 2004; Narayan and Smith, 2005; Yoo, 2005; Altinay and Karagol, 2005) have focused on the casual relationship between electricity consumption and economic growth for several developing countries. This kind of information is useful for understanding the implications of energy policy. We find very mixed results from previous studies, as there is no consensus either on the existence or on the direction of causality. Table 1 reports the results from some recent studies.

Table 1. Evidence from some selected studies

Authors	Variables	Methodology	Country & period	Findings
Jamil and Ahmad (2010)	GDP, electricity price, electricity consumption	Johansen Cointegration, VECM Granger causality	Pakistan 1960-2008	GDP growth causes energy consumption. Growth in output in commercial, manufacturing and agriculture sectors tends to increase EC
Khan and Qayyum (2009)	GDP, electricity price, electricity consumption, number of customers, temperature	ARDL	Pakistan 1970-2006	Income and the number of customers exert positive impact on electricity demand in the long-run as well as in the short run. The price of electricity exerts negative impact on electricity demand in the long run at aggregate as well as disaggregate level.
Aqeel and Butt (2001)	Per capita GDP, per capita energy, gas, electricity, & petroleum consumption	Cointegration test Hsiao's version of Granger causality	Pakistan 1956-1996	GDP growth causes energy consumption GDP growth causes petroleum consumption EC causes GDP No causality in gas consumption and GDP
Mehrara (2007)	GDP per capita, Energy consumption per capita	Panel Cointegration, Panel Granger causality	Oil exporting countries 1971-2002	Unidirectional causality from economic growth to energy consumption
Narayan and Smyth (2008)	GDP, energy consumption, gross fixed capital (all per capita)	Panel Cointegration with and without structural break, Panel causality	G 7 Countries 1972-2002	Capital formation, energy consumption and GDP growth are cointegrated. Capital formation and energy consumption causes positive real GDP growth in the long run.
Ozturk and Acaravci (2010)	GDP, Carbon dioxide emission, energy(all in per capita) consumption, Employment ratio	ARDL	Turkey 1968-2005	Neither carbon emission nor energy consumption cause GDP growth. Employment ratio causes GDP growth
Ghosh (2002)	Per capita GDP, Pper capita electricity Consumption	Engel-Granger approach Standard Granger Causality	India 1950-1997	No cointegration Unidirectional causality from EC to GDP growth
Shiu and Lam (2004)	Real GDP Electricity Consumption	Johansen Cointegration	China 1971-2000	EC causes GDP growth
Morimoto and Hope (2004)	Real GDP , Electricity production	Granger Causality	Sri Lanka 1960-1998	Electricity production causes GDP growth

To the best of our knowledge no study is available which analyzes the causal relationship between electricity demand and economic growth. Two different methodologies are employed to test the causal relationship between electricity demand and real GDP growth. One is Granger non-causality - the Dolado–Lutkepohl test using the Vector Autoregressive (VAR) in levels - and the other is the standard Granger causality test.

3. Methodology and data

There are two main approaches to analyzing the causal relationship between income and energy consumption in empirical studies: the multivariate approach and the bivariate approach. Stern (1993) uses a multivariate vector autoregressive (VAR) model for the USA in the post-war period. Other studies like Stern (2000), Oh and Lee (2004), and Narayan and Smyth (2005)also used multivariate models. These studies usually investigate the relationship between GDP and energy within a production function model. The multivariate model studies includes GDP, energy, labour capital, and technological change.

On the other hand several studies use a bivariate model in detecting the causality between GDP and electricity. For example, Ghosh (2002), Soytas and Sari (2003), and Yoo (2005), among others, have focused just on the directionality of causality. To simplify the analysis we have adopted a bivariate approach to detecting the direction of causality between total electricity consumption and real GDP in Pakistan.

Causality testing in the Granger sense is conventionally conducted by estimating autoregressive or vector autoregressive (VAR) models. Based upon the Granger Representation Theorem, Granger (1988) shows that if a pair of I(1) series are co-integrated there must be a unidirectional causation in either direction. Thus, a common methodology for testing for causality between two time series involves pre-testing for a unit root and co-integration. Conditional upon the results of the unit root test, which are usually Dickey-Fuller type tests in practice, a co-integration test - either the Engle–Granger or the Johansen test - is applied to the pair of series. If co-integration exists, the causality test may be conducted in two ways. First, the integrated data may be used in levels in a bi-variate autoregressive model, due to the super-consistency properties of estimation in the case of co-integration. Secondly, a bi-variate model containing error correction mechanism terms due to the Granger Representation Theorem may be used in causality testing. If the data are integrated but not co-integrated, then causality tests can be conducted by using the first differenced data to achieve stationarity (see Oxley and Greasley, 1998 for a review of causality tests).

Data on electricity consumption in units of kilowatt hours (KWh) and real GDP per capita are taken from IWorld Development Indicators over the period 1960 to 2008.

In order to test the direction of causality between electricity consumption and real GDP, we use the Granger causality test. Then, to find the long-run relationship between electricity consumption and real GDP, the Engel and Granger co integration test has been used. Finally Structural Vector Autoregression (SVAR) has been used for forecasting. With the Granger causality test we can check the direction of causality between two variables. The Granger causality test assumes that the information relevant to the prediction of the respective variables (in our case, electricity consumption and real GDP) is contained solely in the time series data on these variables. The test involves estimating the following pair of regressions:

$$lgdp_t = \alpha_1 + \alpha_2 lec_t + \varepsilon_{1t}$$
$$lec_t = \beta_1 + \beta_2 lgdp_t + \varepsilon_{2t} \quad (1)$$

where $lgdp_t$ and lec_t are log of real GDP per capita and log of electricity consumption and ε_{1t} and ε_{2t} are uncorrelated disturbances. For the existence of a long run relationship, both variables $lgdp_t$ and lec_t should be non-stationary in levels and stationary in first differences.

$$\begin{aligned} \varepsilon_{1t} &= lgdp_t - \alpha_1 - \alpha_2 lec_t \\ \varepsilon_{2t} &= lec_t - \beta_1 - \beta_2 lgdp_t \end{aligned} \quad (2)$$

If ε_{1t} and ε_{2t} are stationary in levels, then we can conclude that both variables are cointegrated.

Cointegration approach

To test the long run relationship between two variables in the Engel-Granger co integration approach, all the variables must be non-stationary in levels and become stationary after taking first differences, and their linear combination is stationary in levels.

Unit Root Test

The use of time series data necessitates the investigation of unit roots in variables as a first step. The augmented Dickey-Fuller (ADF) test is used to test the time series properties of the data.

Vector error correction mechanism (VECM)

When two variables are co-integrated, there is a long run relationship between the two. However there may be disequilibrium in the short run. Therefore the error term can be considered as equilibrium error and this error term can be used to tie the short run behavior of the dependent variable to its long run behavior. The Granger representation theorem states that if a set of I(1) variables or set of non-stationary variables are co-integrated then they can be characterized as being generated by an error correction mechanism (ECM). In an error correction model, the errors in previous periods ε_{1t-1} and ε_{2t-1} summarize the corrections towards the long-run equilibrium. The VECM in two variables case can be written as follows:

$$\begin{aligned} \Delta lgdp_t &= \alpha_1 + \sum_{i=1}^{m} \alpha_{11} \Delta lgdp_{t-i} + \sum_{i=0}^{n} \alpha_{12}\, lec_{t-i} + \delta 1 \varepsilon_{1t-1} \\ \Delta lec_t &= \alpha_1 + \sum_{i=0}^{m} \alpha_{11} \Delta lgdp_{t-i} + \sum_{i=1}^{n} \alpha_{12}\, lec_{t-i} + \delta 2 \varepsilon_{2t-1} \end{aligned} \quad (3)$$

The optimal lag length to be used in the error correction model has been determined using the SBC criterion. The speed of adjustment coefficients δ_1 and δ_2 have very important implications for the dynamics of the system. If δ_1 and δ_2 are negative and statistically significant then VECM exist and this supports the long run relationship.

4. Empirical results

The use of time series data necessitates the investigation of unit roots in variables as a first step. The augmented Dickey-Fuller (ADF) is used to test the time series properties of the data. The results reported in Table 2 show that both variables (*Elc* is log of electricity consumption and *lgdp* is the log of real GDP) are nonstationary in levels but become stationary after taking first differences. Hence both the series are I(1).

Table 2. Results of unit root tests

Variable	**ADF**		**Order of Integration**
	Level	**First difference**	
Elc	-2.003	-5.033***	(1)
Lgdp	-1.388	-5.237***	(1)

Note: The regressions in levels include both intercept and trend whereas in first differences they include the intercept only. *** indicates rejection of null hypothesis of non-stationarity of the variable at the 1% level of significance.

As both variables are I(1), this justifies the use of the Engel-Granger approach to co-integration. In this approach, both variables are non-stationary at level and become stationary after taking the first difference and their linear combination is integrated of order zero, i.e. I (0). Lag order is selected on the basis of AIC and SBC criteria. Both criteria show that lag order is one.

Table 3. Granger causality test

Null Hypothesis:	Obs	F-Statistic	Probability	Decision
LGDP does not Granger Cause LELEC	37	0.98363	0.46338	Do not Reject
LELEC does not Granger Cause LGDP		3.21787	0.02361	Reject

The results reported in Table 3 show that there is unidirectional casualty and it runs from electricity consumption to real GDP per capita. This implies that high electricity consumption causes high real GDP per capita, because electricity is an important input in the production function.

Table 4. Modeling electricity consumption

Variable	Coefficient	Standard Error	t-Statistic	Probability
lec_t	0.341493	0.024429	13.97886	0.0000
C	2.614347	0.253736	10.30343	0.0000
AR(1)	0.787421	0.132422	5.946303	0.0000
Adj R^2 = 0.99				
DW=1.74				

If the residuals term ε_{1t} obtained from the above regression is stationary in levels, then both variables are cointegrated and OLS regression yields super-consistent estimators for the cointegrating parameter. We perform a DF test on the residual series to determine their order of integration. The form of the DF test is the following:

$$\Delta\varepsilon_{1t} = \alpha_1\varepsilon_{1t-1}+v_{1t}$$

We do not include a constant or a time trend and we obtained following results:

$$\Delta\varepsilon_{1t} = -0.9107\varepsilon_{1t-1}$$
$$\tau = -5.5869;\ R^2=0.43;\ DW=1.96$$

The estimated coefficient of ε_{t-1} is negative and highly significant which implies that $\varepsilon_{1t} \sim I(0)$ is stationary in levels. Therefore we can reject the null hypothesis that the electricity consumption and real GDP per capita variables are not cointegrated.

Table 5. Result of ECM (ΔLGDP)

Variable	Coefficient	Standard Error	t-Statistic	Probability
$\Delta LGDP_{t-1}$	1.116868	0.491553	2.27212	0.0304
$\Delta LGDP_{t-2}$	0.396544	0.142022	2.792119	0.0090
ΔLELEC	0.142798	0.059736	2.390475	0.0233
$\Delta LELEC_{t-1}$	0.317627	0.17394	1.82608	0.0778
Ecm_{t-1}	-1.097266	0.519746	-2.11116	0.0432
Adj. R^2 = 0.18				

The results reported in Table 5 show that the coefficient of the residual term is negative and significant, which confirms short run adjustment and support the result of a long run relationship between electricity consumption and real GDP per capita.

Table 6. Modeling GDP per capita (Elc)

Variable	Coefficient	Standard Error	t-Statistic	Probability
C	6.071522	2.951393	2.057172	0.0474
LGDP	0.929931	0.370575	2.509428	0.0170
AR(1)	0.97113	0.013771	70.51747	0.0000
Adj. R^2 = 0.997015				
DW = 2.064884				

Similarly, we perform a DF test on the residual series ε_{2t} to determine order of integration. The form of the DF test is the following:

$$\Delta\varepsilon_{2t} = \alpha_1\varepsilon_{2t-1} + v_{2t}$$

We do not include a constant or a time trend and we obtained the following results:

$$\Delta\varepsilon_{2t} = -1.0603\varepsilon_{2t-1}$$
$$\tau = -6.3925 \qquad R^2=0.54\ DW=1.95$$

We find that the estimated coefficient of ε_{2t-1} is also highly significant with a negative sign which implies that $\varepsilon_{2t} \sim I(0)$ is stationary in levels. Therefore we can conclude that a long-run relationship exists between electricity consumption and real GDP per capita.

Table 7. Results of vector error correction model (dependent variable: D_LELEC)

Variable	Coefficient	Standard Error	t-Statistic	Probability
$\Delta LELEC_{t-1}$	0.813362	0.305473	2.662634	0.0120
ΔLGDP	0.549513	0.408626	1.344782	0.1882
$AR2_{t-1}$	-0.897661	0.346601	-2.58989	0.0143
C	0.000823	0.02288	0.035984	0.9715
Adj. R2 = 0.190109				
DW = 1.667717				

Table 8. Variance decomposition and impulse response function

a) Variance Decomposition of LELEC

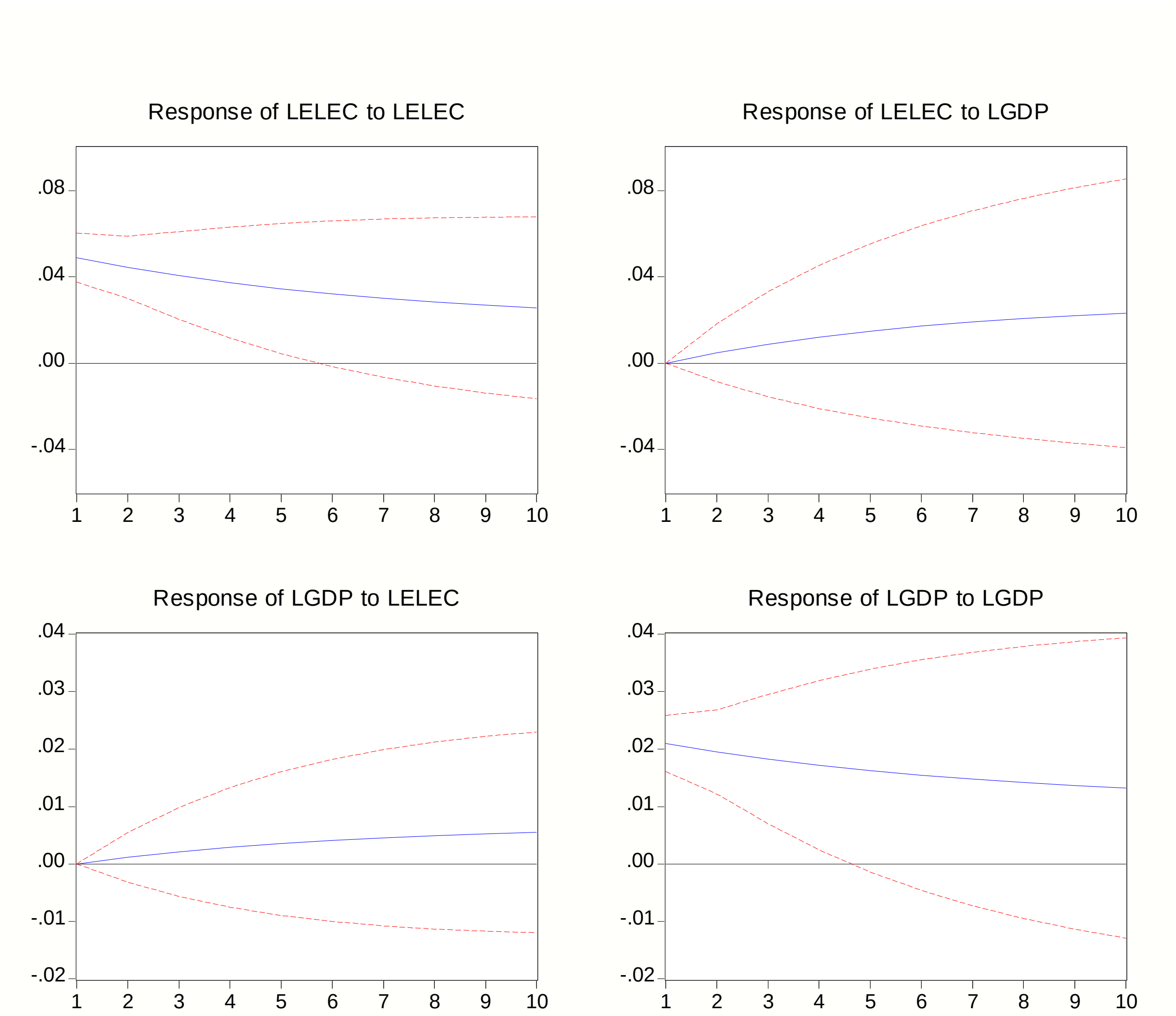
Period	S.E.	LEC	LGDP
1	0.048918	100	0
2	0.067523	99.58151	0.418494
3	0.081057	98.72868	1.271317
4	0.092056	97.56327	2.436727
5	0.101512	96.18941	3.810587
6	0.109923	94.69146	5.308542
7	0.117575	93.13472	6.865284
8	0.124646	91.56774	8.432264
9	0.131250	90.02519	9.974813
10	0.137467	88.53073	11.46927

b) Variance Decomposition of LGDP

Period	S.E.	LEC	LGDP
1	0.020953	16.26479	83.73521
2	0.028945	18.17149	81.82851
3	0.034715	20.01739	79.98261
4	0.039339	21.7865	78.2135
5	0.043243	23.46855	76.53145
6	0.046648	25.0579	74.9421
7	0.049687	26.55239	73.44761
8	0.052441	27.95252	72.04748
9	0.054971	29.26061	70.73939
10	0.057315	30.48028	69.51972

Variance decomposition tables show that at a maximum horizon of ten years, the log of real GDP per capita explains only 11 percent of variation in electricity consumption. Electricity consumption explains 16 percent to 30 percent of variation in the log of real GDP per capita.

Figure 1. Response to Nonfactorized One S.D. Innovations ± 2 S.E.



The impulse response function predicts that a one standard deviation shock to the log of real GDP per capita would cause electricity consumption to rise continuously over the 10 year horizon. Similarly, a one standard deviation shock to electricity consumption would cause a continuous rise in log of real GDP per capita.

5. Conclusion

In this study, the long run relationship between electricity consumption and real GDP per capita has been investigated over the period 1971 to 2008. The evidence of cointegration between these two variables in all the cases indicates the existence of a long-run equilibrium relationship. This implies that although electricity consumption and output may exhibit short term deviations, it eventually returns to long-run equilibrium. The direction of causality between the variables and within sample exogeneity for each variable is detected by employing VECM. The results indicate a unidirectional causal relationship from electricity consumption to economic growth which implies that that electricity is a limiting factor to economic growth. Hence, shocks to electricity supply will have a negative impact on economic growth.

Pakistan is an electricity-deficient country and the electricity sector operates at bare capacity margin. To fulfill increased electricity demand, planning and investment in infrastructure development is essential. The unplanned outages may negatively affect economic growth. The government should adopt a policy so that a sustainable electricity supply may be ensured. There is abundant potential capacity of hydroelectricity in the country that can be tapped by constructing dams.

The pros of hydroelectricity are its low variable cost and lower hazard to the environment than thermal and nuclear power stations. Its cons are its cyclical nature and seasonal fluctuations in water availability. Hence, the electricity sector needs sufficient generation capacity in excess of demand to avoid shortages due to seasonal factors. The authorities need to take steps to increase the supply of electricity.

Acknowledgements. The authors are grateful to Dr Shamim Sahibzada and an anonymous referee for valuable comments. Any remaining errors and omissions are the authors' sole responsibility.

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