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Electricity Demand in Pakistan: A Nonlinear Estimation

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1. INTRODUCTION

Pakistan has plunged into darkness because of severe electricity shortage over the last few years. The electricity shortfall has reached 4,250 MW with demand standing at 16,400 MW and generation at 12,150 MW in June 2013 (PEPCO). The load shedding and power blackouts act as a binding constraint to the economic growth through their impact on employment, trade and poverty [Kessides (2013)]. The existing statistics reveal that Pakistan has witnessed low GDP growth rate during the periods of low or negative electricity growth and during the periods where electricity growth picked up there is an increase in GDP growth rate [Pakistan (2013)]. The power crisis has destroyed the industrial sector of Pakistan. Around 40 percent factories and industry units have now been closed and around 7.5 percent of labour force is out of jobs only because of this dilemma.[1]

The studies on the power crisis amongst other issues such as governance, transmission and distribution losses, circular debt etc. have also highlighted tremendous increase in the demand for electricity as the leading factor contributing to the persistent demand supply gaps. Over the last three decades, there has been an upsurge in the demand for electricity owing to urbanisation, industrialisation, rural electrification, growth in agriculture and service sectors, rapid growth in domestic demand and rising per capita income. The actual demand was not fully anticipated because of the failure to forecast and plan for future, upgrade existing plants and set up new generating stations in the face of rapidly rising demand [Kessides (2013)].

The precise assessment of electricity demand thus remains imperative concern for policy makers in Pakistan. The objective of this paper is to estimate the electricity demand function for Pakistan in nonlinear fashion using time series data over the period 1971–2012. According to best of my knowledge, there is no study that estimates electricity demand function for Pakistan with the possibility of nonlinearity. In this study, the smooth transition regression model has been used to reexamine the relationship

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[1]http://talibmag.com/effects-of-electricity-crisis-in-pakistan/

among electricity consumption, real income, and own energy prices. Using this nonlinear approach, we can identify the economic variables that explain the transition of the electricity consumption-income-price nexus from one regime to another.

The rest of this paper is structured as follow: Section 2 summarises the existing literature concerned with the electricity demand function; Section 3 briefly discusses the electricity sector in Pakistan; Section 4 explains the data sources and estimation methodology to be used here; Section 5 presents our results and Section 6 concludes the study.

2. LITERATURE REVIEW

There are number of studies that estimate the electricity demand function in Pakistan including Masih and Masih (1996), Siddique (2004), Lee (2005), Khan and Qayyum (2009), Jamil and Ahmed (2010), Shahbaz, *et al*. (2012) and Javid and Qayyum (2013) among others. These studies mainly employed causality test and co-integration method to identify the causal association between electricity consumption and economic growth. Few studies have concluded that causality runs from energy consumption to GDP [Masih and Masih (1996); Lee (2005); Aqeel and Butt (2001); Siddique (2004)]. On the other hand, few predicted unidirectional causality from real activity to electricity consumption [Jamil and Ahmed (2010)]. Shahbaz, *et al.* (2012) investigate the linkages between energy consumption and GDP using Cobb-Douglas production function over the period 1972-2011 by employing ARDL method. This study indicates that energy consumption enhances economic growth. The causality analysis confirms the existence of feedback hypothesis between energy consumption and economic growth. Javid and Qayyum (2013) estimated the electricity demand function by employing the structural time series technique over the period 1972-2010 for Pakistan. This study finds that the nature of relationship is not linear and deterministic but stochastic.

The empirical literature provides mixed and conflicting results with respect to the electricity consumption-economic growth nexus. There is no consensus on the direction of causality between electricity consumption and economic growth. This inconsistency in outcome is largely due to the use of different econometric techniques and time periods, among other things. As we discussed, these studies mainly use cointegration method to analyse the energy-economic growth nexus.[2] However, Lee and Chiu (2013) argue that these studies assume that "the cointegration relationship of energy demand model takes a linear function form i.e. considered only linear cointegration framework ignoring the non-linear cointegration, which may lead to the misleading conclusion that no cointegration exists between energy demand and its determinants".

The use of non linear methodologies was later witnessed in several studies. For example Hu and Lin (2008) confirm the non-linear cointegration between GDP and disaggregated energy consumption for Taiwan. This study shows that adjustment process of energy consumption toward equilibrium is highly persistent when an appropriate threshold is reached. Esso (2010) used non-linear cointegration method to estimate the energy demand function for African countries. Gabreyohannes (2010) argues that explanatory power of energy consumption-economic growth model can be improved

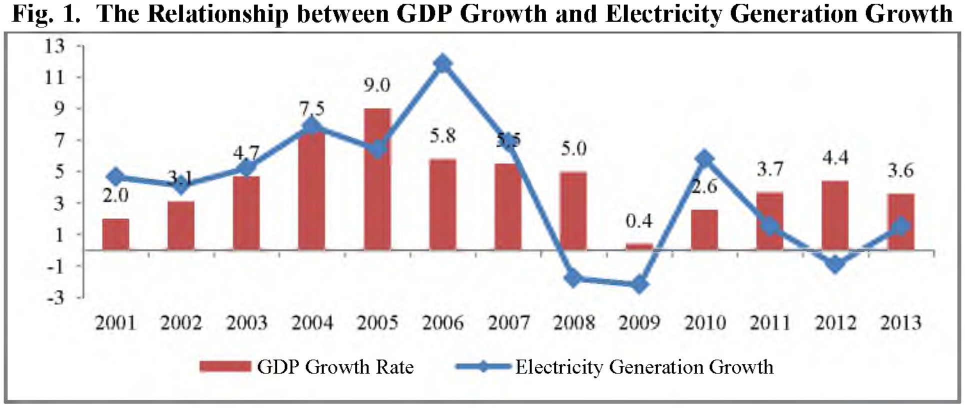
[2]For international see for example Belloumi (2009); Athukorala and Wilson (2010) and so on.

when non-linear effect is included. This helps to design appropriate policies. Thus in this study, we use smooth transition regression model to reexamine the relationship among electricity consumption, real income, and own energy prices for Pakistan using time series data over the period 1971-2012.

3. ELECTRICITY SECTOR IN PAKISTAN

Pakistan has been facing electricity crisis right from its inception to present day. In 1947, Pakistan had capacity to produce only 60 MW for its 31.5 million people and rest was to be imported from India. Pakistan, recently, is producing around 12000 MW with the shortfall of 4000 MW. This crisis has led to formidable economic challenges adversely affecting economic growth. The Figure 1 depicts a strong positive relation between the GDP growth rate and the growth rate of electricity generation.[3] Trend analysis shows that average GDP growth rate remains low during the period of low growth rate of electricity generation. The GDP growth has declined from 5.8 percent in 2006 to 3.6 percent in 2013 when growth rate of electricity generation has declined from 11.8 percent to 1.5 percent during the same period. It is estimated that load shedding and power blackouts have caused a loss of around 2 percent of GDP. The industrial production and exports have been severely affected by power crisis in Pakistan. The growth rate of industrial sector has declined from 7.7 percent in 2007 to 2.7 percent in 2012. A study has shown that industrial output has declined in the range of 12 to 37 percent due to power shortages [Siddiqui, *et al.* (2011)]. The export growth declined from 4.6 percent to –2.8 percent during same period.

Fig. 1. The Relationship between GDP Growth and Electricity Generation Growth



Source: Pakistan (2013).

4. DATA AND METHODOLOGY

4.1. Data

Our empirical analysis is based on time series data covering the period 1971-2012. The data on electricity consumption and output is obtained from World Development Indicators (WDI). For electricity consumption, we have used electric power consumption

[3]The simple correlation between these two variable is 0.513.

(kWh) per capita. The electric power consumption measures the production of power plants and combined heat and power plants less transmission, distribution and transformation losses and own use by the heat and power plants. For output, we have used GDP per capita at constant local currency units. GDP per capita is gross domestic product divided by midyear population. The data on prices is collected from various issues of the *Pakistan Energy Year Book*. The average real prices are derived by adjusting for CPI. The log transformation is applied on all the variables.

4.2. Methodology

The stationarity properties of the variables are examined using standard unit root test such as Augmented Dickey Fuller (ADF) test and Philips-Perron (PP) test. However, in the presence of a structural break, the standard ADF tests are biased towards the non-rejection of null hypothesis. Shahbaz and Lean (2012) pointed that the standard unit test such as AD and PP may provide inefficient and biased estimates in the presence of structural break in the data.

To overcome this problem, we have used unit root test proposed by Saikkonen and Lutkepohl (2002) and Lanne, *et al.* (2002). The model with structural break is considered $y_t = \mu_0 + \mu_1 t + f_t(\theta)'\gamma + \epsilon_t$. Where $f_t(\theta)'\gamma$ represents the shift function while θ and γ are unknown parameters and ϵ_t is error term generated by $AR(p)$ process with unit root. A simple shift dummy variable with the shift date T_B is used on the basis of exponential distribution function. The function $f_t = d_t \begin{Bmatrix} 0 & t < T_B \\ 1 & t \geq T_B \end{Bmatrix}$ does not involve any parameters θ in the shift term $f_t(\theta)'\gamma$ where γ is a scalar parameter. Differencing this shift function leads to an impulse dummy. We follow Lanne, *et al.* (2002) to choose the structural breaks exogenously which allows us to apply ADF-type test to examine the stationarity properties of the series. Once a possible break is fixed, a more detailed analysis may be useful to improve the power of the test. The critical values are tabulated as in Lanne, *et al.* (2002).

After establishing the time series properties of the variables, we estimated electricity demand function for Pakistan. To estimate linear demand function for comparison purpose with the existing literature, we apply Autoregressive distributed lag (ARDL) bound testing approach to cointegration proposed by Pesaran, *et al.* (2001) to examine the long run relationship between the variables.[4] To examine the stability of the ARDL bounds testing approach to cointegration, we apply stability test namely CUSUM and CUSUMSQ. Akaike Information Criteria (AIC) is used to select the optimal lag length.

To estimate nonlinear electricity demand function, we employ smooth transition autoregressive model (STAR) introduced by Teräsvirta (1998)—the most significant regime switching model.[5] The STAR models are widely used to estimate nonlinear relations for time series data because of their smooth transition mechanism in different regimes. In contrast to threshold autoregressive models that use indicator function to control the regime switching process, STAR models make use of logistic and exponential function for this purpose. Various studies have shown that these models can fit the

[4]For more detail on ARDL see Pesaran, *et al.* (2001).
[5]For more detail on STAR see Teräsvirta (1998).

regime switching mechanisms properly for evaluation of nonlinear dynamism of variables [Van Dijk and Teräsvirta (2002)]. After fitting the nonlinear model, various diagnostic tests are used to check the adequacy of the proposed model including serial correlation, uneven variance and normality tests.

5. EMPIRICAL RESULTS

The descriptive statistics analysis and correlation matrix among the variables are presented in Table 1. This analysis gives information on the mean, range and the scale of the relationship between the variables. The descriptive statistics show that the average electricity consumption per capita is 5.5 kWh. The average GDP per capita is Rs 10.04 and average real price of electricity is Rs 1.29. The correlation coefficient matrix shows that output and prices have positive and significant correlation with the electricity consumption.

Table 1

Descriptive Statistics

Statistics	L_nE_t	L_nO_t	L_nP_t
Mean	5.50	10.04	1.29
Maximum	6.16	10.48	1.68
Minimum	4.49	9.58	0.78
Std. Dev.	0.55	0.27	0.25
Observations	42	42	42
Correlation			
L_nE_t	1.0000		
L_nO_t	0.9826*	1.0000	
L_nP_t	0.7768*	0.7125*	1.0000

Note: The * represents the significant correlation.

The time series properties of the data are tested using augmented Dickey-Fuller (ADF) and Phillips-Perron (PP) statistics. The results of ADF and PP tests on the integration of the variables are reported in Table 2. The results indicate that all variables are non-stationary at level. Further, all variables turn out to be stationary after applying difference transformation indicating that all variables are integrated of order one.

Table 2

Results of the Unit Root Test

Variables	ADF Intercept	ADF Intercept and Trend	PP Intercept	PP Intercept and Trend	Results
L_nE_t	–2.02	–0.18	–2.02	–0.24	Non-stationary
ΔL_nE_t	–5.42	–6.24	–5.44	–6.25	Stationary
L_nO_t	–0.90	–1.74	–0.29	–1.85	Non-stationary
ΔL_nO_t	–5.87	–5.83	–4.56	–4.97	Stationary
L_nP_t	–2.17	–2.63	–2.02	–1.68	Non-stationary
ΔL_nP_t	–4.56	–4.97	–4.56	–5.00	Stationary

Note: The critical values are –3.60, –2.94 and –2.61 at 1 percent, 5 percent and 10 percent respectively with intercept and –4.20, –3.52 and –3.19 at 1 percent, 5 percent and 10 percent respectively with intercept and trend.

To confront the possibility of structural break, we have used test proposed by Saikkonen and Lutkepohl (2002) and Lanne, *et al*. (2002). The results of Saikkonen and Lutkepohl unit root test are presented in Table 3. We use an impulse and shift dummy to detect the structural break in all variables. The electricity consumption per capita is stationary at first difference with presence of structural break in 1992. The implementation of structural adjustment program and shift of electricity generation mix from hydro to thermal are the foremost sources of this structural break. The real GDP per capita is stationary at first difference and has a structural break in 1980 that primarily occurs due to policy reversal from nationalisation to privatisation. The electricity prices are stationary at first difference with structural break in 1996.

Table 3

Saikkonen and Lütkepohl Unit Root Test

Variables	Impulse Dummy	Shift Dummy	Break
L_nE_t	–2.44	–2.45	1992
ΔL_nE_t	–5.00***	–3.60***	1992
L_nO_t	–0.96	–1.35	1980
ΔL_nO_t	–5.25***	–3.44**	1980
L_nP_t	–2.81	–2.48	1996
ΔL_nP_t	–4.20***	–2.92**	1996

Note: Critical values [Lanne, *et al.* (2002)] are –3.48, –2.88 and –2.58 at 1 percent (***), 5 percent (**) and 10 percent (*) respectively.

The long run and short rum impact of output and prices on electricity consumption are estimated using ARDL bound testing approach to cointegration. The appropriate lag length is one based on the AIC. The F-statistics that we obtained for the demand function is 5.8 which support the hypothesis of cointegration for the proposed model (Table 4). These results confirm the long rum relationship between the electricity consumption, output and prices.

Table 4

Result of Bounds Testing to Conintegration

F-Statistic	95% Lower Bound	95% Upper Bound
5.8068	4.1556	5.2670

We also apply Johansen and Juselius (1990) cointegration approach to confirm the robustness of a long run relationship among the variables. The results confirm the existence of a long run relationship among electricity consumption, output and prices (Table 5). These findings also reveal that long run relationship is valid and robust.

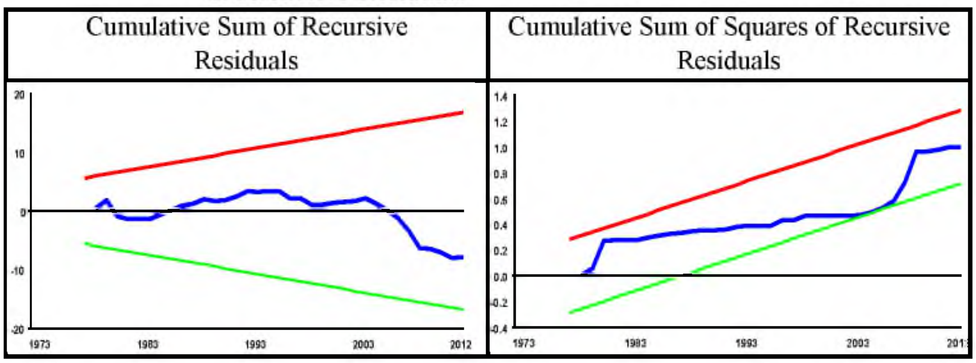
Table 5

Results of Johansen Cointegration Test

Hypothesis	Trace Statistics	Max-Eigen Statistics
None *	41.20099***	28.29968***
At most 1	12.90131	7.715994
At most 2	5.185311	5.185311

The autoregressive distributed lag model has been employed to estimate electricity demand function in linear fashion. This is done for the sake of comparison with the earlier literature. The results are presented in Table 6. We have used various diagnostic tests to ensure that the model is adequately specified. F-statistics confirms the adequacy of the estimated model. The results of serial correlation test, normality test and heteroscedasticity test are consistent with requirements. The CUSUM and CUSUMSQ tests are applied to examine the stability of long run parameters and results are plotted in Figure 2. The figure portraits that plotted data points are within the critical bounds implying that the long run estimates are stable. The straight lines represent critical bounds at 5 percent significance level.

Fig. 2. Plot of Cumulative Sum and Cumulative Sum of Squares of Recursive Residuals



The long run estimates show that output has a positive impact on electricity consumption implying that increasing level of development amplifies the demand for electricity consumption. The estimated coefficient is 1.3 which is statistically significant at 1 percent level showing that 1 percent increase in GDP per capita raises demand for electricity by 1.3 percent. This indicates that electricity demand is highly sensitive to the development of overall economy. Our findings are comparable with the existing literature [see e.g. Javid and Qayyum (2013)]. The long run estimates further exhibit that electricity prices have a positive impact on electricity consumption. The estimated coefficient is 0.56 which is statistically significant at 1 percent level implying that 1 percent increase in prices leads to 0.5 percent increase in electricity consumption. The small value of coefficient indicates that consumption is not reactive to price change. Further, the positive association signifies that prices are below the optimal level.

The short run estimates show that GDP per capita has a positive influence on electricity consumption. The estimated coefficient is 0.24 which is significant at 10 percent level implying that increase in the growth rate of GDP per capita by 10 percentage points increases the growth of electricity consumption by 2.4 percentage points. Similarly, electricity prices have a positive and significant impact on electricity consumption. The estimated coefficient is showing that 10 percentage points increase in the growth of prices causes escalation in electricity consumption by 1 percentage point. It is also noted that the coefficient of lagged error correction term is negative and statistically significant at 1 percent level of significance. The significance of error correction term supports the established relationship among the variables. The negative coefficient implies that the deviation in the short run towards long run is corrected by 18 percent from the previous period to the current period.

Table 6

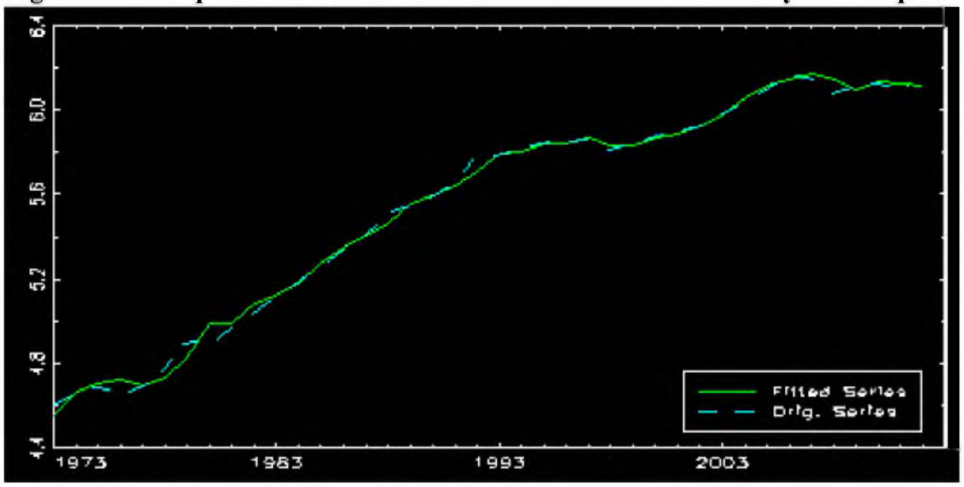
ARDL Estimates (1,0,0)

Variables	Coefficient	Std. Error	T-Statistics
	Long Run Results		
LnO_t	1.3064	0.27648	4.7252***
LnP_t	0.56351	0.22063	2.5541***
Constant	–8.1680	2.6323	–3.1030***
	Short Run Results		
ΔLnO_t	0.24089	0.13495	1.7850*
ΔLnP_t	0.10390	0.03926	2.6465***
ECM_{t-1}	–0.18438	0.07053	–2.6140***
R^2		0.31	
F-Statistics		5.45***	
Serial Correlation		0.60246[.438]	
Normality Test		0.86242[.650]	
Heteroscedasticity Test		0.79563[.372]	

The first step in the estimation of STAR model is to select appropriate transition variable from all variables existing in model and the one with the highest probability of rejecting the null hypothesis of linearity will be chosen as the transition variable. The results show that the transition variable is electricity prices and appropriate mode is logistic smooth transition autoregressive model with one of type 1 (LSTAR1). Selecting electricity prices as the threshold variables, the LSTAR1 nonlinear model is considered for modelling the electricity demand in Pakistan.

The estimation results of LSTAR1 model are presented in Table 7. We have used various diagnostic tests to ensure that the model is adequately specified. The results of normality test are consistent with requirements. The results show that there is no autocorrelation error in the LSTAR1 model. The residuals of nonlinear LSTAR1 model are even with variance; therefore there is no variance unevenness in the model. The absence of variance unevenness and serial autocorrelation in the residuals of this model add to the reliability of the obtained results. The comparison between the real trend and the fitted trend of electricity consumption is presented in Figure 3.

Fig. 3. The Comparison between Real and Fitted Trend of Electricity Consumption



The two regime model indicates that the slope coefficient equals 12.8, which signifies a rather fast transition from one regime to another. The threshold extreme of the mode is 1.46—the anti-logarithmic value is 4.32 as the real price of electricity. The average real electricity price is Rs 3.88 which is below the threshold level i.e. Rs 4.32. These results are consistent with the findings of linear model where we argue that the positive association between electricity price and electricity consumption is mainly due to the reason that the prices are below the optimal price level. The estimation results further show that the impact of price becomes insignificant after reaching the threshold level. The estimated coefficient of electricity consumption is insignificant in the non-linear part of the model.

For further explanation on the estimation results of the model, two extreme regimes of the model, that is the mode in which transition function is considered as 0 and 1 (G=0, G=1), are specified as below:

First extreme regime (G=0)

$$LnE_t = -0.93 + 0.83LnE_{t-1} + 0.17LnO_t + 0.17LnP_t$$

Second extreme regime (G=1)

$$LnE_t = -9.63 + 0.45LnE_{t-1} + 01.22LnO_t + 0.26LnP_t$$

The estimated coefficient of output is positive and statistically significant in both regimes implying that output per capita is the major determinant of electricity demand in Pakistan. However, the influence of GDP per capita is greater during the second regime.

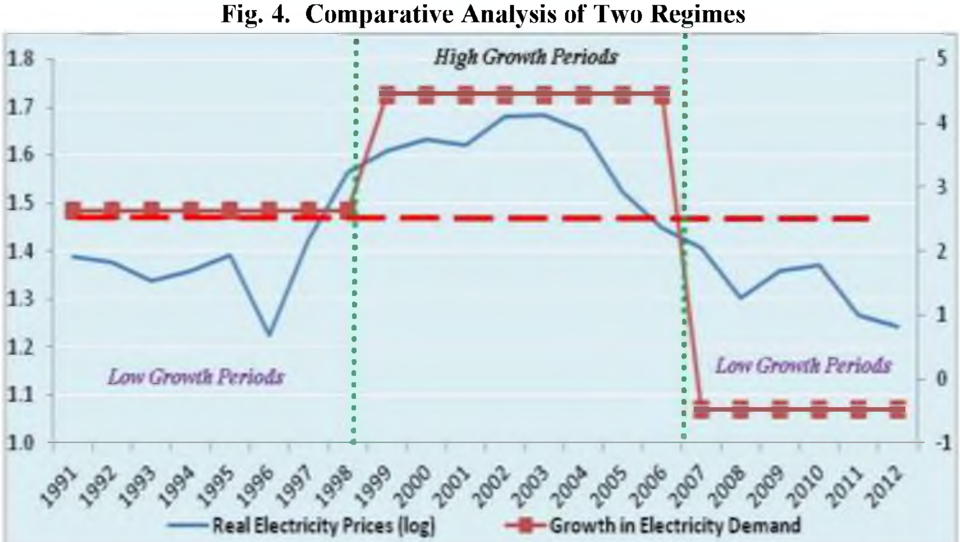
Based on these findings, it can be concluded that electricity demand in Pakistan follows an asymmetric pattern. The demand has strongly been influenced by GDP during high growth period 1999-2006. The price effect during this period has remained insignificant. Whenever, prices are below the threshold level, prices have significant positive impact on the electricity demand. The Figure 4 demonstrates the relationship among electricity prices, GDP per capita growth and average electricity demand.

Table 7

STAR Model with Logistic Transition Function Estimates

Variables	Coefficient	Std. Error	T-Statistics
The Linear Part of the Model			
L_nE_{t-1}	0.8288	0.0806	10.285***
L_nO_t	0.1694	0.0530	3.1962***
L_nP_t	0.1686	0.0566	2.9790***
Constant	–0.9372	1.1275	–0.8312
The Non-Linear Part of the Model			
L_nE_{t-1}	–0.3825	0.2219	–1.7238*
L_nO_t	1.0547	0.5003	2.1082**
L_nP_t	0.0904	0.2666	0.3394
Constant	–8.6937	4.0496	–2.1468**
Slope Parameter γ	12.869	15.643	0.8227
Threshold Extreme C	1.4639	0.0487	30.054***
$\bar{R}^2$		0.99	
ARCH-LM Test [p-Value(F)]		0.50	
Normality Test (JB Test) [p-Value(Chi^2)]		0.12	
Test for Autocorrelation (no-autocorrelation) [p-Value]		0.73	

Fig. 4. Comparative Analysis of Two Regimes



The time span from 1991 to 2012 is divided into two regimes. Regime 1 with prices below the threshold level during 1991-1998 and 2007-2012 and regime 2 with price above the threshold level over the period 1999-2006. The figure shows that during regime 2, the average growth in the electricity demand was around 5 percent coupled with high economic growth and electricity prices. On the other hand, the growth in the electricity demand was low during regime 1 in which the growth was also low and prices were below the optimal level.

6. CONCLUDING REMARKS

The present study has estimated the linear and nonlinear electricity demand function for Pakistan using time series data over the period 1971-2012. The study has employed logistic smooth transition regression model for estimation. Time series properties have shown that all variables are stationary at first difference with the possibility of structural break. The estimation results have shown that there is a long run relationship among electricity consumption, GDP per capita and electricity prices.

In the long run, electricity consumption is primarily determined by the level of development. The elasticity of electricity consumption with respect to GDP per capita is greater than unity. The contribution of GDP per capita in determining the demand for electricity is more than unity in high growth period. These observations suggest that continuous investment in electricity generation is required to meet the future requirement of electricity.

The further analysis has shown that the price of electricity has minor impact on electricity consumption. The small value of coefficient indicates that consumption is not reactive to price change. The nonlinear estimation has shown that the average prices of electricity are below the threshold or optimal level. The positive association holds till the prices have reached the optimal level. The prices beyond the optimal level have insignificant contribution to the electricity consumption. These findings suggest that electricity demand is insensitive to the changes in the electricity prices especially beyond the threshold level. The obvious reason for the fragile relationship between electricity demand and electricity prices is lack of alternatives for electricity. Electricity is the main source of energy in Pakistan. The cost of easily available alternative such as oil is higher than the electricity prices. This forces the utilisation of electricity even under increasing prices. The availability of cheap alternatives such as coal, gas or other renewable sources will change the dynamics of the relationship between electricity consumption and electricity prices.

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Comments

I would like to congratulate authors for presenting latest estimates on electricity demand in Pakistan. This study is part of the research projects funded by the Pakistan institute of Development Economics to promote innovative research ideas and novelty in techniques needed to explore burning energy issues of Pakistan. This study makes useful contribution in the existing literature by estimating electricity demand with the new time series model L-STAR – logistic smooth transition model or two regime switching model. This technique distinguishes this study from the earlier contributions in that the former studies have assumed linear relationships in between economic growth or per capita income and electricity demand and used cointegration technique for testing the assumption. The study is well structured as all sections have been properly organized and have coherence. The study provides latest estimates on electricity demand and its relationship with electricity prices and per capita income in Pakistan using data for 1971–2013.

However this study needs to improve on two weaknesses. First, the study has used non-linear technique by using reference of the work done earlier by researchers not in Pakistan. Only a few studies have been mentioned in the section on literature review and more could have been explored. Furthermore, this study has used cointegration technique and found long run relationship between electricity demand, per capita income and electricity prices which is conflicting with the justification for using non-linear technique. This requires on authors to either review the introduction of the study or use other grounds for nonlinear technique use in Pakistan.

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