Electricity Demand in Pakistan: A Nonlinear Estimation

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Abstract: This study attempts to estimate the electricity demand function for Pakistan using smooth transition autoregressive (STAR) model over the period 1971-2012. The nonlinear estimation has shown that the elasticity of electricity consumption with respect to GDP per capita is greater than unity. The findings suggest that under optimistic growth scenario of around 6 percent per annum, the required growth for electricity generation is around 9 percent per annum. Continuous investment on electricity generation is required to meet the future requirement of electricity. The average prices of electricity are below the threshold or optimal level. The prices beyond the optimal level have insignificant contribution to the electricity consumption implying that electricity demand is insensitive to the changes in the electricity prices beyond the threshold level. The weak relation between electricity demand and electricity prices is primarily due to lack of alternatives for electricity. 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.

Key words: *Electricity demand, Smooth Transition Autoregressive Model, Pakistan*

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1. Introduction

Pakistan has plunged into darkness because of severe electricity shortage over the last few years. Electricity shortfall has reached 4,250 MW with demand standing at 16,400 MW and generation at 12,150 MW in June 2013 (PEPCO). Load shading 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 reveals that Pakistan has witnessed low GDP growth rate during the periods of low or negative electricity growth and while periods where electricity growth picked up there is increase in GDP growth rate (GoP, 2013). Power crisis dreadfully obliterate industrial sector of Pakistan. Around 40 percent factories and industry units are now been closed and around 7.5 percent of labor force is out of job only because of this dilemma[2].

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 factors contributing to the persistent demand supply gaps. Over the last three decades, there is immense upsurge in the demand for electricity owing to urbanization, industrialization, rural electrification, growth in agriculture and service sectors, rapid growth in domestic demand and rising per capita income. 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 always 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 among electricity consumption, real income, and own energy prices. Using this 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 summarizes the existing literature concerned with the electricity demand function; section 3 briefly discusses the historical development of electricity sector in Pakistan; section 4 sketches the modeling framework of the study; section 5 explains the data sources and estimation methodology to be used here; section 6 presents our results and section 7 concludes.

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

2. Literature review

2.1.Determinants of electricity demand

To design appropriate energy policy, it is important to identify all the possible determinants of electricity demand. The growing population, extensive urbanization, rural electrification, industrialization, rapid growth in domestic demand and rising per capita income have contributed to an increase in the demand for electricity during the last decade. Amongst these, the income, population and energy prices are considered critical determinants of electricity demand (Al-Ghandoor *et al.* 2009).

A number of studies have shown that there is strong positive relationship between electricity consumption and income in the country – the GDP per capita is taken as a proxy to measure income level (see e.g. Jumbe, 2004; Reiss and White, 2005; Athukorala and Wilson, 2010; Jamil and Ahmad, 2010; Javid and Qayyum, 2013). Ghosh, (2002) and Chen *et al.* (2007) argue that the impact of economic growth on electricity consumption has taken place through various channels. First, economic growth caused expansion in the industrial and commercial sectors where electricity has been used extensively. Second, electricity consumption in agriculture and transport sector has also accelerated to keep pace with country's economic growth. Third, households, because of their higher disposable income, have become more and more dependent on the electric gadgets. Therefore, a permanent increase in economic growth may results in a permanent increase in electricity consumption.

The existing literature has shown a robust relationship between electricity prices and electricity consumption (see e.g. Al-Faris, 2002; Amarawickrama and Hunt, 2008; Jamil and Ahmad, 2010; Inglesi-Lotz, 2011; Javid and Qayyum, 2013, Tang and Tan, 2013). These studies highlight that there exists a negative relationship between electricity price and electricity consumption, but this relationship is less significant as compared to the relationship between GDP and electricity consumption. Inglesi and Blignaut (2011) conclude that the economic growth of the country has proven to be one of the main drivers of electricity consumption. Javid and Qayyum (2013) argue that there are limited or no options for consumers to switch from electricity to other sources of energy in response to electricity prices.

2.2.Empirical Studies

There are number of studies that estimate the electricity demand function in Pakistan – includes 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 run from energy consumption to GDP (Masih and Masih, 1996; Lee, 2005; Aqeel and Butt, 2001; Siddique, 2004). On the other hand, few predict 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) estimate 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 analyze the energy-economic growth nexus[3]. 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 may lead to the misleading conclusion that no cointegration exists between energy demand and the 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 persistence when an appropriately 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 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.

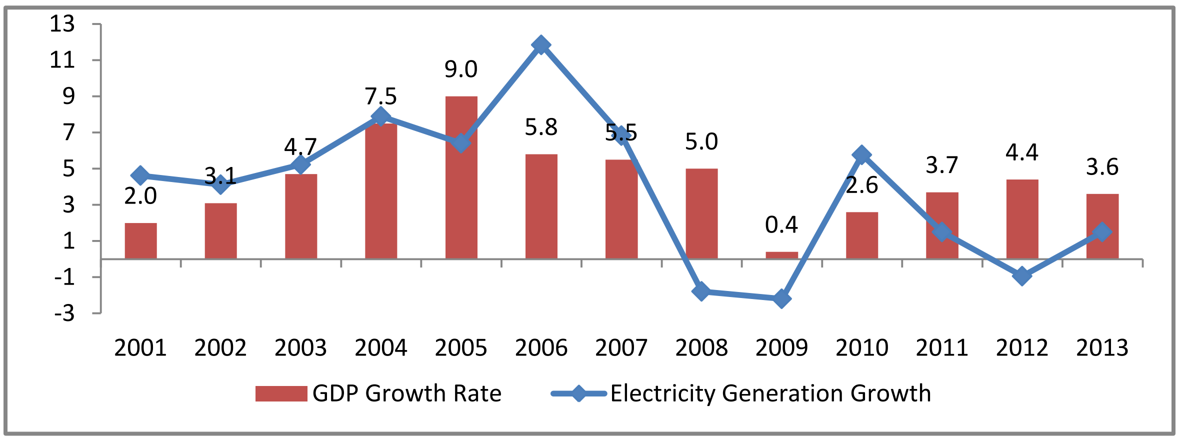
3. Electricity sector in Pakistan

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

[3] For international see for example Belloumi, 2009; Belke *et al.* 2011; Athukorala and Wilson, 2010 and so on

imported from India. Pakistan, recently, is producing around 12000 MW with the shortfall of 4000 MW. This crisis has led to formidable economic challenges. Load shedding and power blackouts have adversely affected economic growth. The figure 1 depicts a strong positive relation between the GDP growth rate and the growth rate of electricity generation[4]. 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 (Abbasi, 2007). 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 has declined from 4.6 percent to -2.8 percent during same period.

Figure 1: The Relation between GDP Growth and Electricity Generation Growth



Source: GoP, 2013

3.1. Electricity Sector: Historical development

Pakistan had capacity to produce only 10.7MW electricity using *HYDEL* in 1947. In 1956, Pakistan established Atomic Energy Research Center to meet the energy requirements. . In 1958, energy generation capacity rose to 115MW through nuclear power generation. In 1958, Water and Power Development Authority (WAPDA) was formed to provide cohesive development schemes in water and power sectors. WAPDA established an intensive network of power distribution lines throughout the country. WAPDA embarked on this task by increasing the power generation capacity to 119MW executing a number of *HYDEL* and thermal power generation projects. WAPDA increased the electricity generation capacity to 636MW from

[4] The simple correlation between these two variable is 0.513

119MW and 781MKWH till 1965. During the 1960's Pakistan signed agreement with India known as Indus water Treaty. The Indus water Treaty guaranteed 10 years of continual water supply and provided for construction of replacement works called Indus Basin Projects (IBP's). Under this treaty, two dams i.e. *MANGLA* Dam and *TERBELA* Dam with 1000 MW and 3478 MW installed capacities were constructed. Moreover, five barrages and a gated siphon were also constructed under this treaty. *WARSK* Dam was also constructed with the generation capacity of 243MW. In 1963 WAPDA with USAID assisted set up a coal power plant in Quetta having two units 7.5 MW capacity each. During 1970s, with the setting up of a number of *HYDRO* and thermal power units, the installed capacity rose from 636MW in 1970 to 13331MW in 1975. The construction of *MANGLA* Dam and *TERBELA* Dam was completed in late 1970s. After the construction of *MANGLA* Dam and *TERBELA* Dam Pakistan's energy mix heavily tilted towards hydro power. The energy mix was approximately 60 percent *HYDEL* and 40 percent thermal in 1984. After *TERBELA* Dam, WAPDA could not construct any big dam, except 1450MW *GHAZI BROTHA* hydro power project in 2004.

In the 1980's the electricity generation capacity touched 3000 MW. Even though, there was fast development in energy sector in 1980s, Pakistan suffered from intense power shortage, mainly due to inability of WAPDA to install new power projects to cater to the electricity demand. With each passing year, electricity demand increased to fulfill the requirements of the country's development i.e. urbanization, industrialization and rural electrification.

In 1985 and 1986, the government started HUB power project and *LAKHRA* power generation plant with the help of World Bank to accomplish the energy requirements. The government allow private sector to install thermal power plants in 1988. As a result, the first private power project, the Oil based Hub power project (HUBCO) began 1991. The gross installed capacity of this thermal power plant is 1,292 MW while its net capacity is 1200MW. It is 2nd largest IPP in Pakistan, KAPCO being the largest one. This project set the basis for tariff setting of subsequent IPP's and had a miscellany effect on the financial condition of WAPDA and the country.

The government adopted a strategic plan for power sector privatization in 1992. Under this plan WAPDA was gradually privatized. The Pakistan Electric Power Company (PEPCO) was formed in 1992; the thermal power generation facilities of WAPDA were restructured into Generation Companies (GENCOs), the distribution network of WAPDA was divided into nine Distribution Companies (DISCOs) and given in PEPCO's control and a National Transmission and Dispatch Company (NTDC) was formed under PEPCO. The private sector would be invited to construct operate new thermal generation plants and a thermal project. Since this policy attracted mostly thermal projects, it resulted in a change in the hydro/thermal generation mix. Independent regular would be established in support of this policy.

From 1992-2007 electricity generation more than double with both *HYDEL* and thermal power generations playing a role, but the major role was played by thermal which increased the power generation cost. WAPDA was restricted from constructing new dams. Besides this power policy 1994 bound WAPDA/KESC to buy the power produced by IPP's at mutually agreed rates. Most of the IPP's established under the power policy 1994 and several units of GENCO's were based on oil. Many of them were latterly converted into natural gas because generation cost is lower. However this was done without realizing that indigenous gas resources are not sufficient to supply fuel to all of the units. In 1997, the National Electric Power Regulatory Authority (NEPRA) was created to grant licenses for generation and transmission of electric power and to determine tariffs for generation, transmission, and distribution companies.

Till 2005, the total supply of electricity was surplus to demand by around 450MW. Since then, with the increase in demand of power, little supply was added to the system. However, Pakistan was hit by its worst power crises in 2007. Production fell by 6,000 MW and massive shutdowns followed suit. In 2008, availability of power in Pakistan fell short of the demanded by 15%. Load shedding blackouts became more and more severe. Moreover, the existing power stations and energy distribution networks were damaged during in the 2005 earthquake and 2010 floods.

4. Modeling Framework

The electricity demand is function of various factors such as output, prices, technology and level of development (Howard *et al*. 1993). The studies, however, frequently employ GDP, electricity price as an argument to determine the income and price elasticities. These elasticities have been used to forecast future demand and design appropriate policy (Varian, 1988). In modeling electricity demand function, we chose the simple standard Cobb-Douglas type function form with constant elasticity of scale.

$$E_t = A_t O_t^{\beta} P_t^{\gamma} \tag{1}$$

Where E_t is electricity consumption, O_t represents real output and P_t electricity price. A_t is the deterministic term measured as $A_t = C_0 \exp(dt)$ where C_0 is a constant and (dt) is a linear time trend β and γ are the demand elasticities with respect to real output and electricity price respectively. After applying log transformation and substituting the value of A_t, it can be written as follow:

$$\log(E_t) = \log C_0 + dt + \beta \log(O_t) + \gamma \log(P_t) \tag{2}$$

The current electricity demand also depends on the previous year's demand. For this purpose we incorporate the lag of electricity consumption as an explanatory variable in the model. The modified dynamic model can be written as:

$$\log(E_t) = \log C_0 + dt + \alpha \log(E_{t-1}) + \beta \log(O_t) + \gamma \log(P_t) + \varepsilon \qquad (3)$$

The expected sign of lagged value of electricity consumption is positive implying $\alpha > 0$. The expected sign of output is positive meaning $\beta > 0$. The prices can have positive or negative sign depending upon the level of development and possibility of alternative energy options. This implies $\gamma \gtreqless 0$. ε is the error term.

As we discussed earlier that the relation among electricity consumption, output and prices is not linear. To incorporate the possibility of non-linearity in the model, we consider two-regime logistic smooth transition regression (STR) model. The standard STR model with a logistic transition function has the following form:

$$\log(E_t) = \alpha + b_1 \log(O_t) + c_1 \log(P_t) + (b_2 \log(O_t) + c_2 \log(P_t))G(q_{t-j}, \gamma, \theta) + \varepsilon_t \qquad (4)$$

Where $G(q_{t-j}, \gamma, \theta)$ is a transition function of the observable variable q_{t-j}. To investigate the differences of the relationship among electricity consumption, real GDP and electricity prices for higher and lower than the threshold variable, we employ a logistic transition function as follows:

$$G(q_{t-j}, \gamma, \theta) = \left[1 + exp\left(-\gamma(q_{t-j} - \theta\,)\right)\right]^{-1} \qquad (5)$$

Where the parameter γ determines the slope of the transition. Furthermore, the restriction $\gamma > 0$ is imposed for identification, and it determines the smoothness of the transition i.e. the speed of the transition from one regime to another.

5. Data and Estimation Methodology

5.1. Data

Our empirical analysis is based on time series data covering the period 1971-2013. Data on electricity consumption and output are obtained World Development Indicators (WDI). For electricity consumption, we have used electric power consumption (kWh) per capita. 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. Data on prices are collected from various issues of the Pakistan Energy Years Book. The average real prices are derived by adjusting with CPI. Log transformation is applied on all variables.

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 relation between the variables. The descriptive statistics show that the average electricity consumption per capita is 5.5 kWh. The average GDP per capita is 10.04 and average real price of electricity is 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	LnE_t	LnO_t	LnP_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			
LnE_t	1.0000		
LnO_t	0.9826*	1.0000	
LnP_t	0.7768*	0.7125*	1.0000

Note: the * represents the significant correlation.

5.2.Estimation 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, Perron (1989) argues that 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 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. Critical values are tabulated in Lanne *et al*. (2002).

After establishing the time series properties of the variables, we estimate 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[5]. To examine the stability of the ARDL bounds testing approach to cointegration, we apply tability 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 Teräsvirta (1998) – the most significant regime switching model[6]. 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 o control the regime switch process, STAR models make use of logistic and exponential function for this purpose. Various studies have shown that these models can fit the regime switch 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 include serial correlation, uneven variance and normality tests.

6. Empirical Results and Discussions

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**		**PP**		**Results**
	Intercept	**Intercept & trend**	**Intercept**	**Intercept & trend**	
LnE_t	-2.02	-0.18	-2.02	-0.24	Non stationary
ΔLnE_t	-5.42	-6.24	-5.44	-6.25	Stationary
LnO_t	-0.90	-1.74	-0.29	-1.85	Non stationary
ΔLnO_t	-5.87	-5.83	-4.56	-4.97	Stationary
LnP_t	-2.17	-2.63	-2.02	-1.68	Non stationary
ΔLnP_t	-4.56	-4.97	-4.56	-5.00	Stationary

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

[5] For more detail on ARDL see Pesran et al. (2001)
[6] For more detail on STAR see Teräsvirta (1998)

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 hyro to thermal are the foremost sources of structural break. The real GDP per capita is stationary at first difference and has a structural break in 1980 that primarily occur due to policy reversal from nationalization to privatization. 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
LnE_t	-2.44	-2.45	1992
ΔLnE_t	-5.00***	-3.60***	1992
LnO_t	-0.96	-1.35	1980
ΔLnO_t	-5.25***	-3.44**	1980
LnP_t	-2.81	-2.48	1996
ΔLnP_t	-4.20***	-2.92**	1996

Note: critical values (Lanne *et al*. 2002) are -3.48, -2.88 and -2.58 at 1% (***), 5% (**) and 10% (*) 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. Results confirm the existence of long run relationship among electricity consumption, output and prices (table 5). These findings reveal that long run relationship is valid and robust.

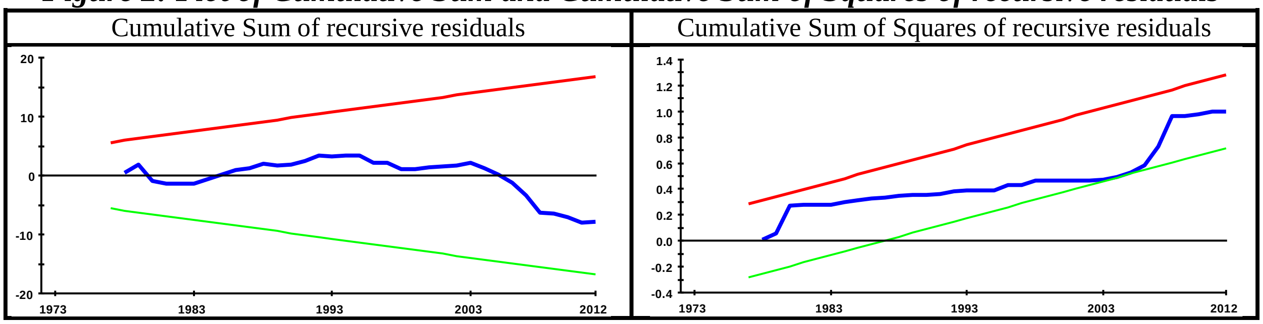
Table 5: Results of Johansen cointegration test

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

6.1. Linear Model: ARDL Estimates

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.

Figure 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 one percent increase in GDP per capita raises 1.3 percent demand for electricity. 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 one 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 one 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)

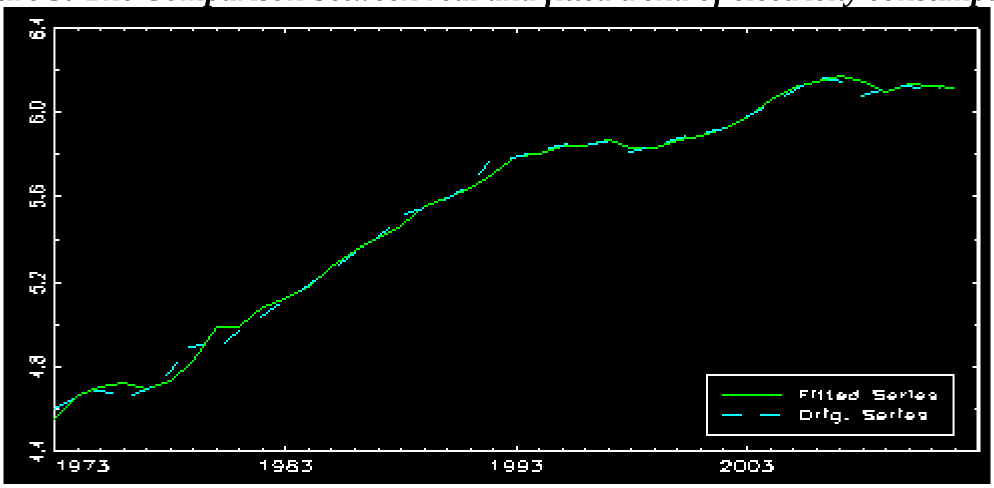
Variables	**Coefficient**	**Std. Error**	**T-Statistics**
	Long Run Results		
LnO_t	1.3064	0.27648	4.7252***
LnP_t	0.56351	0.22063	2.5541***
Constant	-8.1680	2.6323	-3.1030***
	Short Run Results		
ΔLnO_t	0.24089	0.13495	1.7850*
ΔLnP_t	0.10390	0.03926	2.6465***
ECM_{t-1}	-0.18438	0.07053	-2.6140***
R^2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

6.2.Non-Linear Model: LSTAR Estimates

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 modeling 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. 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.

Figure 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), is specified as below:

First extreme regime (G=0)

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

Second extreme regime (G=1)

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

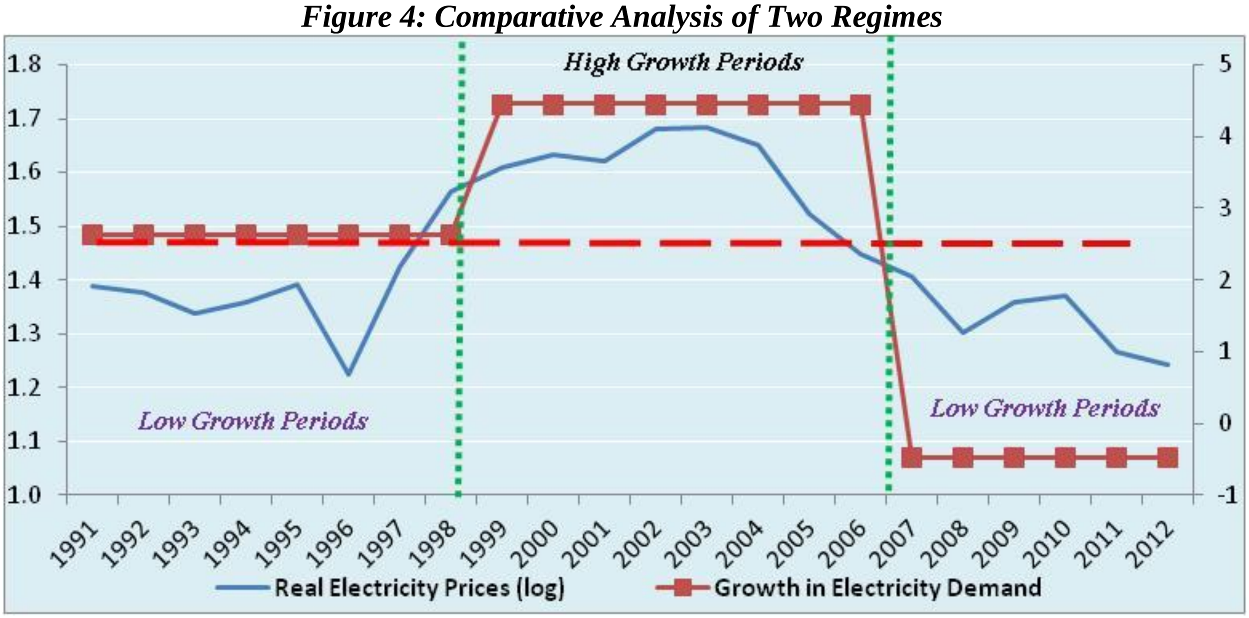
The estimated coefficient of output is positive and statistically significant in both regimes implying that output per capita is the major determinants for electricity demand in Pakistan. However, the influence of GDP per capita is greater during the second regime.

Table 7: STAR model with logistic transition function estimates

Variables	**Coefficient**	**Std. Error**	**T-Statistics**
	The Linear Part of the Model		
LnE_{t-1}	0.8288	0.0806	10.285***
LnO_t	0.1694	0.0530	3.1962***
LnP_t	0.1686	0.0566	2.9790***
Constant	-0.9372	1.1275	-0.8312
	The Non-Linear Part of the Model		
LnE_{t-1}	-0.3825	0.2219	-1.7238*
LnO_t	1.0547	0.5003	2.1082**
LnP_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

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.

Figure 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 show 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.

7. 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 autoregressive distributed lag model and 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. One percent increase in GDP per capita boosts electricity consumption by 1.3 percent. The impact of GDP per capita has remained more than unit in the nonlinear estimation.

The contribution of GDP per capita in determining the demand for electricity is more than unity under high growth period. Under pessimistic growth scenario of around 4 percent per annum, around 6 percent growth is required in the electricity generation. On the other hand, under optimistic growth scenario of around 6 percent per annum, the required growth for electricity generation is around 9 percent per annum. These observations suggest that continuous investment on 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 utilization 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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