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Revisiting income and price elasticities of electricity demand in Pakistan

Hanan Ishaque

Department of Economics, Alpen Adria University, Klagenfurt, Austria

ABSTRACT

In view of a more than decade-long power crisis in Pakistan, several studies have estimated income and price elasticities of electricity demand. These estimates are based on electricity consumption data that do not reflect actual demand due to an electricity supply shortfall of up to 6000 megawatts (MW). Moreover, previous studies accounted for power consumption data of only one of the two electric power companies, Pakistan Electric Power Company (P.E.P.C.O.), ignoring the other company K-Electric, with a share of over 15% in country's electricity consumption. This study attempts to revisit electricity demand elasticities in Pakistan at the aggregate and sectoral level by including both P.E.P.C.O. and K-Electric and adjusting the consumption series for load shedding to reflect actual electricity demand. By employing an Autoregressive Distributive Lag model, the study finds electricity demand to be income elastic at aggregate level and in the agriculture sector in the long run, and relatively inelastic in the industrial sector. However, unlike previous studies, the electricity demand is price inelastic at all levels, which is an expected outcome in an economy facing electricity shortages. The coefficients of short-run income and price elasticities are smaller than their long-run counterparts. No evidence of cointegration is found for the commercial sector.

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1. Introduction

Pakistan's power sector has been in the grip of a serious crisis. According to the National Electric Power Regulatory Authority, the electricity supply shortfall in the country reached 5782 MW in the year 2013. Total demand for electricity approached 21605 MW while the supply lagged behind at 15823 MW. The ensuing power cuts of up to 12 h a day had an adverse effect on the economy to the extent of 2% of G.D.P., as estimated by the Ministry of Finance (2013). The economy witnessed a period of high economic growth from 2004 to 2008, averaging 6.6%, which caused electricity demand to grow by 9.5% on average during the same period. The crisis started to emerge in 2008 and continues as generation capacity

CONTACT Hanan Ishaque h1ishaque@edu.aau.at

fell short of the growing demand. Besides investigation into institutional bottlenecks responsible for the current predicament, an analysis of electricity demand is imperative.

Many authors have analysed electricity demand in Pakistan using different econometric methods (see for example, Siddiqui (2004); Khan and Qayyum (2009); Chaudhry (2010); Jamil and Ahmad (2010) and Shahbaz and Feridun (2012)). There is a near consensus that economic growth stimulates electricity demand in the long run. The Planning Commission (Planning Commission, G. of P 2014) put forward Pakistan Vision 2025 that aims at high economic growth in the next decade and outlines a plan for socio-economic development. Research and past trends suggest that, if the growth targets materialise, there will be high demand for energy in general and electricity in particular. The task of meeting the current deficits and future needs of the economy is indeed daunting. Analysis of electricity demand is thus critical from academic and policy perspectives. The estimates of income elasticity of electricity demand help policy-makers forecast the surge in demand emanating from economic growth.

Electricity demand elasticities for Pakistan have been estimated by various authors including Alter and Syed (2011), Jamil and Ahmad (2011), Khan and Qayyum (2009), Iqbal (1983), Tariq, Nasir, and Arif (2008), and Zaman, Khan, Ahmad, and Rustam (2012). The results of these studies differ widely, owing to the use of different econometric techniques and inaccurate electricity consumption statistics.[1] These studies were based on the power market statistics of P.E.P.C.O., the biggest power company, and do not include consumption of electricity generated by K-Electric, the other company, which has a share of around 15.5% of the country's total electricity consumption (NTDC, 2013). Secondly, using electricity consumption data without adjusting for excess demand makes demand elasticity estimates spurious, as electricity consumption is constrained by stagnant generation capacity and there has been a deficit of up to 20% of electricity demand since 2004. For instance, in the case of income-elastic electricity demand, economic growth should trigger electricity consumption, but due to insufficient supply, the resulting increase in demand only adds to the power deficit instead of increasing power consumption. Therefore, the elasticity estimates based on actual electricity consumption in a power-deficient market may be rather inaccurate. In 2014 alone, there was a difference of over 29000 GWh in actual electricity consumption and the consumption where there had been no load shedding.[2]

Thirdly, almost all the studies find aggregate electricity demand to be price elastic, which does not make intuitive sense as electricity is heavily subsidised and the government spends 1.5% of the G.D.P. on tariff differential subsidies. There is already a huge deficit in electricity demand and supply, and electricity is not available to all classes of consumers for the better part of the day. Jamil and Ahmad (2011) asserted that substitution of electricity by other fuels is low in Pakistan which, when coupled with the unavailability of electricity despite huge demand, also indicates that the demand ought to be inelastic with respect to price. Low impact of electricity prices on demand in a similar scenario of excess demand and power subsidies has been documented by Ziramba (2008) and Amusa, Amusa, and Mabugu (2009) for South Africa, and by Bildirici and Kayıkcı (2012) in the case of selected European economies. They found elasticity demand at aggregate level and for the residential sector to be inelastic in the power-deficient and subsidised electricity market in South Africa. Considering the power crisis in Pakistan and the importance of elasticity estimates in demand management and pricing policies, there is a need to plug the gaps in existing research to arrive at reliable estimates of electricity demand elasticities.

The objective of this study is to reinvestigate the all-important electricity demand elasticities. Using electricity consumption adjusted for load shedding to reflect actual demand and including consumption and prices data from K-Electric, the study aims at estimating revised income and price elasticities of electricity demand at aggregate and sectoral levels by employing the Autoregressive Distributive Lag (A.R.D.L.) method.

The remainder of the study is organised as follows. Section 2 presents a brief survey of literature on the subject with a focus on Pakistan's power sector. Section 3 provides details about the data, choice of variables and model specification. Sections 4 and 5 explain econometric methodology and the empirical results, respectively, and section 6 concludes.

2. Literature review

Knowledge of the determinants of electricity demand and its responsiveness to economic growth and prices is vital for evidence-informed policy-making (Dergiades & Tsoulfidis, 2008). For the same reason, electricity demand analysis and price and income elasticities have been investigated for countries of different economic and geographical backgrounds. There have always been debates in research about methodology, and researchers have rarely unanimously favoured one particular method over the others. The disagreement among researchers about the robustness of results using certain econometric methods has led to improvement in econometric techniques. Earlier studies investigating electricity demand focused on finding the direction of causality between macroeconomic variables and electricity consumption. Improvement in econometric techniques enabled researchers to analyse different dynamics of demand with accuracy and precision. More recent studies employ different methodologies, ranging from the univariate approach of Engle and Granger (1987) to the multivariate approaches of Johansen (1991), Johansen and Juselius (1990) and the A.R.D.L. approach proposed by Pesaran and Shin (1999). A large number of studies investigated electricity demand using the Johansen cointegration approach; for example, Akmal and Stern (2001) for the residential sector in Australia, Al-Faris (2002) for Gulf Cooperation Countries at aggregate level, Lin (2003) at aggregate level for China, Zachariadis and Pashourtidou (2007) for the residential and services sector for Cyprus, and Jamil and Ahmad (2011) at aggregate and sectoral levels for Pakistan.

Johansen's approach has its limitations while using variables of different order of integration, and Mah (2000) argues that it is not robust for small sample sizes. On the contrary, the A.R.D.L. framework allows the use of variables irrespective of their order of integration and provides consistent short-run and long-run estimators (Pesaran & Shin, 1999). This approach has been widely used to analyse electricity demand. These studies include Halicioglu (2007), Ziramba (2008), and Adom, Bekoe, and Akoena (2012) for residential sector analysis, and De Vita, Endresen, and Hunt (2006), Amusa et al. (2009), Odhiambo (2009) and Zaman et al. (2012) for aggregate electricity demand analysis. Some studies have attempted to employ different econometric approaches and compare the results. Beenstock, Goldin, and Nabot (1999) argue that the results are sensitive to the choice of methodology. The literature reveals that income, electricity price, prices of substitute fuels, temperature and number of electricity consumers are determinants of electricity demand. Almost all the studies find electricity demand to be income elastic and relatively less price elastic. The long-run estimates are higher than their short-run equivalents.

Table 1. Income and Price elasticities of electricity demand in Pakistan at aggregate and household level by various authors.

Author	Method	Elasticity	Aggregate	Household
(Jamil & Ahmad, 2011)	Johansen Maximum Likelihood	Income	1.56	1.97
		Price	−1.27	−1.22
(Alter & Syed, 2011)	Johansen Cointegration	Income	0.25	2.51
		Price	−0.85	−1.74
(Khan & Qayyum, 2009)	ARDL	Income	4.72	0.92
		Price	−1.64	−0.25
Zaman et al. (2012)	ARDL	Income	0.97	–
		Price	–	–
(Tariq et al., 2008)	ARDL	Income	–	1.29
		Price	–	−0.77
(NTDC, 2014)	O.L.S.	Income	–	0.88
		Price	–	−0.12
(Iqbal, 1983)	O.L.S.	Income	–	2.94
		Price	–	−0.22

Source: Author calculation.

Table 1 presents a summary of the studies that used different methods and variables to estimate electricity demand elasticities in Pakistan. The aggregate long-run income and price elasticities range from 0.25 to 4.72 and –0.85 to –1.64, respectively, which points towards large differences in results. The results of these studies vary with the choice of econometric methodologies, which in this case include simple ordinary least squares, Johansen Maximum Likelihood, and A.R.D.L. estimation. Each of these methods has its own limitations when dealing with time series data. Therefore, the choice of methodology is key to accurate elasticity estimation. According to Bentzen and Engsted (2001), A.R.D.L. is the most widely used time series approach in energy analysis. A comparison of certain techniques by Fatai, Oxley, and Scrimgeour (2003) also leads to the conclusion in favour of A.R.D.L. owing to its flexibility and better forecast performance. High price elasticity of aggregate electricity demand in a country with high power deficit and tariff subsidies, as found most of the studies, is also intriguing. Most of the research in Pakistan's context finds electricity demand at aggregate level to be income elastic. But the results are spurious, as the electricity consumption data used do not reflect demand, which is almost 20% in excess of supply. This study uses load shedding-adjusted data of electricity consumption, unlike previous studies, at aggregate and sector level, and employs the A.R.D.L. method to allow the use of variables with different orders of integration.

3. Model specification and data

We begin the analysis of electricity demand in Pakistan by following the basic demand model employed by Al-Faris (2002). The general form of the model could be specified as;

$$Q_t^* = X_t \beta^* + \varepsilon_t \tag{1}$$

where Q_t^* is the electricity consumption which can be represented as a function of a vector of exogenous variables. Apart from income level and electricity prices as the major determinants of electricity demand, prices of substitute fuels, appliance prices and changes in temperature feature in the vector X_t. This study includes income, electricity price and number of electricity subscribers in the exogenous variables vector. The temperature variable is not included following Amusa et al. (2009), who argue that temperature as an explanatory variable for electricity demand is not very relevant when there is little variability in temperature between years. In Pakistan, yearly temperature variations are negligible. This argument is supported by Jamil and Ahmad (2011), who did not find any significant impact of temperature on electricity demand at aggregate and sector level except in the commercial sector. They also found that price of substitute fuels does not explain electricity demand in Pakistan, so we include only price of electricity as an explaining factor in our analysis.

We follow the econometric specification used by Ziramba (2008) and Amusa et al. (2009) for South Africa's aggregate and residential demand analysis, respectively. The model is extended by including number of electricity consumers in different sectors. A few studies, including Lin (2003) for China and Zaman et al. (2012) for Pakistan, used population as a determining factor. However, Pakistan is yet to be fully electrified, and to capture the impact of electrification in the country, number of subscribers is included in the model instead of population. To parameterise electricity demand at aggregate and sector levels, the following econometric specification is employed;

$$Ln\left(EC_t\right) = \beta_0 + \beta_1 Ln(Y_t) + \beta_2 Ln\left(P_t\right) + \beta_3 Ln(C_t) + \mu_t \quad (2)$$

where EC_t is the amount of electricity consumed in Gigawatt hours (GWh), Y_t represents economic output (G.D.P.) at constant prices of 2005–06, P_t is the weighted average real price of electricity and C_t is the number of electricity consumers. Data on all these variables are available at aggregate and sector level. $_t$ represents white noise error process and is assumed to have normal distribution. All the variables are expressed in natural logarithms. In this study, the total electricity consumption series from both electric power companies at aggregate and sector level is augmented by amount of electricity required to meet the power deficit. Adjusting power deficit or load shedding in actual consumption is important, as the responsiveness of electricity demand to income and prices is reflected in higher power deficit instead of higher consumption, since the supply constrains further consumption. N.T.D.C. (2013) computes yearly power deficit and electricity generation required to meet the deficit. Subtracting transmission and distribution losses from required excess generation gives an estimate of electricity consumption if excess demand were met. Horizontal summation of actual electricity sales of P.E.P.C.O. and K-Electric and estimated sales required to meet excess demand generates a series of electricity consumption reflecting actual demand.

The study uses an annual time series data for all the variables. Data on real G.D.P. at aggregate and sector levels are collected from world development indicators (The World Bank, 2014). Electricity consumption data, electricity requirement to meet excess demand and number of customers in different sectors are collected from Pakistan's National Transmission and Dispatch Company (N.T.D.C.). Average real electricity prices per kilowatt-hour are obtained from N.T.D.C. and K-Electric. Weighted average real electricity price series at aggregate and sector level is constructed by assigning weights according to the number of customers served by each company. The study period spans from 1972 to 2013.

4. Econometric methodology

4.1. Unit roots tests

The analysis begins with the unit root tests. We employ Dickey Fuller Generalised Least Squares (D.F.-G.L.S.) unit root test proposed by Elliott, Rothenberg, and Stock (1996) which is a modified version of Dickey Fuller *t*-test, has stronger power in the presence of trend and unknown mean and is efficient for small samples. However, it does not consider the possible structural break in the data due to some shock. To deal with this, we also use the test devised by Perron (1997) that allows endogenously determined structural break in the data that causes change in the slope. It follows a two-step procedure; first the series is de-trended by the following regression equation:

$$y_t = \mu + \beta t + \gamma DT_t^* + \tilde{y}_t \tag{3}$$

where $DT_t^* = 1(t > T_b)(t - T_b)$

The unit root test is then performed using *t*-statistic on the following regression with = 1

$$\tilde{y}_t = \alpha \tilde{y}_{t-1} + \sum_{i=1}^{k} c_i \Delta \tilde{y}_{t-1} + e_t \tag{4}$$

where T_b is the break date representing time of occurrence of change in the trend function and k is the truncation lag. Both are endogenously determined in the model. Perron (1997) maintains that the results are robust to alternative specifications of Zivot and Andrews (2002) for selection of break date and truncation lag.

4.2. A.R.D.L. bounds-testing approach to cointegration

The next step involves exploring the existence of long-run equilibrium relationship among our selected variables using the A.R.D.L. bounds-testing approach developed by Pesaran, Shin, and Smith (2001). The A.R.D.L. bounds-testing approach is adopted for multiple reasons. Firstly, it allows estimation for a mix of I(0) and I(1) variables. Secondly, the double log linear model specification used in the analysis yields elasticities necessary for demand management. Thirdly, the long-run estimates generated by the A.R.D.L. method are unbiased irrespective of possible endogeneity among some independent variables (Odhiambo, 2009).

Therefore, the following unrestricted error correction model (E.C.M.) specification is used in the analysis with electricity consumption as dependent variable:

$$\begin{aligned}\Delta LnEC_t = {} & \beta_0 + \beta_1 T + \beta_2 LnEC_{t-1} + \beta_3 LnY_{t-1} + \beta_4 LnP_{t-1} + \beta_5 LnC_{t-1} + \sum_{i=1}^{p} \beta_6 \Delta LnEC_{t-i} \\ & + \sum_{j=0}^{q} \beta_7 \Delta LnY_{t-j} + \sum_{k=0}^{r} \beta_8 \Delta LnP_{t-k} + \sum_{l=0}^{s} \beta_9 \Delta LnC_{t-l} + \mu_t \end{aligned} \tag{5}$$

where lag orders p,q,r and s are chosen using Akaike Information Criteria (A.I.C.) as this is superior to other criteria and has less mean prediction error (Shahbaz, Kumar Tiwari, & Nasir, 2013). The appropriate lag structure makes error term $_t$white noise. The above model is estimated for both aggregate and sector level models. 'T' is added in the equation to capture time trend but is excluded in case it turns out to be insignificant. The bounds testing involves testing for the existence of a cointegration relationship using the *F*-test suggested by Pesaran et al. (2001) for joint significance of coefficients of lagged level variables. For that purpose, the null hypothesis of no cointegration denoted by $F_{EC}(EC|Y_t, P_t, C_t)$, where electricity consumption is the dependent variable while respective G.D.P., prices and number of customers are treated as long-run forcing variables in aggregate and sector level model, would be

$$H_0: \beta_2 = \beta_3 = \beta_4 = \beta_5 = 0$$

against the alternative hypothesis

$$H_1: \beta_2 \neq \beta_3 \neq \beta_4 \neq \beta_5 \neq 0$$

The estimated *F*-statistics against the null hypothesis are compared with two bounds of critical values of *F*-statistic suggested by Narayan (2005) for different model specifications. The critical value bounds correspond to I(0), I(1) and mutually integrated regressors. If the computed *F*-statistic exceeds the upper bound value, the null hypothesis of no cointegration is rejected (Narayan & Smyth, 2005). However, if it falls below the lower bound, it is concluded that there is no cointegration among variables. A value between upper and lower bounds leads to inconclusive inference.

After long-term cointegration is established, the A.R.D.L. representation of E.C.M. as in Farhani, Shahbaz, Arouri, and Teulon (2014) can be specified for Equation (2) as follows;

$$\begin{aligned}\Delta LnEC_t =&\theta_0 + \theta_1 T + \sum\nolimits_{i=1}^{p} \theta_2 \Delta LnEC_{t-i} + \sum\nolimits_{j=0}^{q} \theta_2 \Delta LnY_{t-j} \\ &+ \sum\nolimits_{k=0}^{r} \theta_2 \Delta LnP_{t-k} + \sum\nolimits_{l=0}^{s} \theta_2 \Delta LnC_{t-l} + \lambda ECT_{t-1} + \xi_t\end{aligned} \tag{6}$$

where Δ is the first difference operator, ξ_t is the disturbance term and $ECT_{t\text{-}1}$ is the error correction term which is a residual series generated from Equation (2). The error correction term signifies speed of adjustment after deviation of the dependent variable from its mean in long run, and its coefficient must be negative and significant in the presence of long-run cointegration (Jalil, Mahmood, & Idrees, 2013).

5. Empirical results

5.1. Unit root tests

The D.F.-G.L.S. unit root test reveals that all the variables are I(1) and none of them is I(2), allowing us to continue with the A.R.D.L. approach. The results are not presented due to space constraints. However, the results of Perron (1997) unit root test with one structural break are presented in Table 2. Following Perron (1997), k_{max} was selected to be 4 in most cases, the results were also checked by increasing lags up to 9 for robustness of truncation lag *k*. The results reveal that sectoral G.D.P., electricity price and number of customers in commercial sector are stationary at level, while all the four variables for aggregate, industrial and agriculture sector level are I(1). This mix of I(0) and I(1) variables lends credence to preferring A.R.D.L. bounds testing over other cointegration methods.

5.2. Test for cointegration

According to Bahmani-Oskooee and Goswami (2003), the bounds test for cointegration involves computing *F*-statistics ,which is sensitive to the number of lags in each first differenced equation above. A.I.C. has been considered to select appropriate lag. According to Enders (2014), a maximum of 3 lags is sufficient to capture time series dynamics of the data, so the maximum number of lags is set to be 3. Onafowora and Owoye (2014) also

Table 2. Perron (1997) unit roots test, with structural break in slope (trend).

	Variables	Break date	*t*-stat	*k*		Variables	Break date	*t*-stat	*k*
Aggregate	Lelec		−3.19	2	Commercial	Lelec		−3.99	2
	Δlelec	1980	−5.99*	0		Δlelec	1992	−5.19**	0
	Lgdp		−2.57	0		Lgdp	1989	−4.49***	3
	ΔLgdp	1980	−5.47*	0		ΔLgdp		−4.99	0
	Lcust		−3.03	0		Lcust	1989	−5.41**	2
	ΔLcust	1997	−4.71***	4		ΔLcust		−9.8	0
	Lprice		−4.22	0		Lprice	1998	−5.21*	0
	ΔLprice	1979	−8.63*	0		ΔLprice		−9.96	0
Industry	Lelec		−3.15	2	Agriculture	Lelec		−2.51	0
	Δlelec	1980	−4.68***	0		Δlelec	2000	−6.39*	0
	Lgdp		−2.27			Lgdp		−4.33	0
	ΔLgdp	1981	−5.39**	0		ΔLgdp	1987	−8.57*	0
	Lcust		−3.8	3		Lcust		−3.93	0
	ΔLcust	2000	−6.91*	0		ΔLcust	1993	−6.14*	
	Lprice		−3.08	0		Lprice		−2.66	0
	ΔLprice	1978	−6.47*	0		ΔLprice	1979	−6.09*	0

Note: The figures in () are *t*-statistics.
*1% level of significance; **5% level of significance; ***10% level of significance.
Source: Author calculation.

Table 3. A.R.D.L. bounds test results.

F (Elec | G.D.P., Price, Cust)				
Variable	Wald *F*-Statistic		Results	
Aggregate	4.72		Cointegration	
Industry*	4.72		Cointegration	
Commercial	2.74		No Cointegration	
Agriculture	6.06		Cointegration	
Critical Values (Pesaran et al., 2001)				
Unrestricted intercept and no trend[a]			Unrestricted intercept and unrestricted trend[b]	
	Upper bound	Lower bound	Upper bound	Lower bound
1%	5.06	3.74	4.40	5.72
5%	4.01	2.86	3.47	4.57
10%	3.52	2.45	3.03	4.06

[a]Critical values with $k = 3$ for all models expect the industrial sector model, where $k = 4$ as it includes unrestricted time trend.
[b]Critical values for industry sector model.
Source: Author calculation.

suggest using 3 lags to have sufficient explanatory power and degrees of freedom while simultaneously dealing with autocorrelation and functional form errors.

The results of bounds tests when electricity consumption at aggregate and respective sector levels is a dependent variable, and economic output (G.D.P.), electricity price and number of consumers are forcing variables, are depicted in Table 3. Time trend was only significant in the industrial sector model and was dropped from other models. The results show that the estimated *F*-statistics for the equations of aggregate level, industrial and agriculture sectors are greater than the upper critical bounds at 1% level of significance. The computed *F*-statistic is compared with critical bounds developed by Pesaran et al. (2001). The null hypothesis of no cointegration can be rejected, and the existence of a long-term relationship is affirmed except for the commercial sector, where no evidence of cointegration is revealed. This implies that economic output, electricity prices and number of customers have long-run cointegration with electricity demand at aggregate level and industrial and agriculture sectors.

After establishing the cointegration among selected variables, the next step is to determine the long-run and short-run elasticities of electricity demand with respect to income, prices and number of electricity consumers at aggregate and sectoral levels.

5.3. Long-run and short-run elasticities

5.3.1. Income elasticity

At the aggregate level, the income elasticity of electricity demand has an expected positive sign and is statistically significant at the 1% level in both short and long run. Tables 4 and 5 present the results of long-run and short-run elasticities of electricity demand, respectively, at aggregate and sector levels. The coefficient of income elasticity at the aggregate level in the long run is 1.7, and it is 0.79 in the short run. The results are consistent with the findings of Jamil and Ahmad (2011), who estimated the long-run elasticity to be 1.56; however, our estimate is slightly higher, perhaps because the consumption data are adjusted for load shedding.

In the industrial sector model, the coefficient of income elasticity in the long run is positive and significant at 5%, implying that a 1% increase in output of the sector increases electricity consumption by 0.6%. The short-run measure of electricity demand elasticity is not different from the long-run counterpart. The low elasticity in the long run, which otherwise is expected to be higher than short-run elasticity, can be attributed to investment in and use of energy-efficient production over time.

In agriculture, a 1% increase in output leads to a 1.24% rise in electricity consumption in the long run. The result is significant at the 1% level. In the short run, the coefficient of income elasticity is 0.19, although insignificant. The possibility of cointegration in the commercial sector has already been ruled out by the bounds test.

5.3.2. Price elasticity

The price elasticity of electricity demand at aggregate level in the long run has, as expected, a negative sign and is significant at the 1% level (Table 4). However, electricity demand is inelastic to price with a coefficient of –0.46. This contradicts earlier studies, for example Khan et al (2009), Jamil and Ahmad (2011), etc. However, low price elasticity makes intuitive sense for a country running high electricity deficits and already subsidised tariffs. The short-run coefficients as presented in Table 5 are smaller than those of the long run. In the industrial sector model, the coefficient of price elasticity is –0.43 and is significant at the 1% level in the long run, and falls to –0.21 in the short run. In the agriculture sector model, electricity demand is more price elastic than in the industrial sector and overall economy, but is still below unity. The long-run and short-run coefficients are –0.79 and –0.41, respectively, at the 1% significance level.

5.3.3. Responsiveness to number of electricity customers

The results in Table 4 and 5 show that the number of electricity customers in the industrial and agricultural sectors is an important determinant of electricity consumption. However, at the aggregate level, its coefficient is small and insignificant in both long run and short run. In the industrial sector, a 1% increase in the number of customers increases electricity

Table 4. Estimated Long-run Elasticities using the A.R.D.L. approach. A.R.D.L. (3, 0, 0, 3) selected based on A.I.C.

Dependent Variable: **Log(Elec)t**

42 observations from 1972–2013

	Log(GDP) *t*-1	Log(Price) *t*-1	Log(Cust) *t*-1
Aggregate	1.707*	−0.462*	0.035
	(3.64)	(−3.91)	(0.10)
Industrial	0.599**	−0.431*	2.766*
	(2.29)	(−3.27)	(5.19)
Agricultural	1.242*	−0.79*	0.984*
	(4.95)	(−6.94)	(3.93)

Note: The figures in () are *t*-statistics.
*1% level of significance.; **5% level of significance.
Source: Author calculation.

Table 5. Estimated Short-Run Elasticities using the A.R.D.L. approach. A.R.D.L. (3, 0, 0, 3) selected based on A.I.C.

Dependent Variable: **Log(Elec)t**

42 observations from 1972–2013

	Log(GDP) *t*-1	Log(Price) *t*-1	Log(Cust) *t*-1	ECM_{t-1}
Aggregate	0.79*	−0.10	0.016	−0.46*
	(3.52)	(−1.56)	(0.10)	(−6.15)
Industrial	0.60*	−0.21**	1.15*	−0.41*
	(3.89)	(−2.56)	(5.62)	(−4.71)
Agricultural	0.20	−0.41*	0.76*	−0.77*
	(0.45)	(−2.96)	(3.35)	(−5.13)

Note: The figures in () are *t*-statistics
*1% level of significance.; **5% level of significance.
Source: Author calculation.

consumption by 2.76% in the long run and 1.15% in the short run. According to N.T.D.C. (2014) the average electricity consumption per customer in the industrial sector is 40 times that of average domestic electricity consumption. A 1% increase in industrial customers would therefore have a much higher impact on electricity consumption in the sector.

In agriculture, a 1% increase in the number of customers leads to 0.98% higher electricity consumption in the long run and 0.76% in the short run. Not surprisingly, electricity consumption is thus sensitive to change in number of customers.

The coefficient of error correction terms in all three models, as shown in the last column of Table 5, are negative and highly significant, corroborating the existence of a long-run relationship among variables. In the aggregate model, the coefficient of ECM_{t-1} is –0.46, which implies that 46% of the deviation from long-run equilibrium in electricity consumption is corrected every year. In the industrial sector model, the system adjusts by 41% in case of shock that takes it away from long-run equilibrium. In the agriculture sector model the adjustment to long-run equilibrium is rather swift, at 77%.

5.4. Diagnostic Tests

The results of diagnostic tests for the three models are presented in Table 6. The serial correlation test is based on the Lagrange multiplier approach, Ramsey's R.E.S.E.T. test which

Table 6. Diagnostic tests.

	Serial Correlation	Functional Form	Normality		Heteroskedasticity
	χ^2	χ^2	χ^2		χ^2
Aggregate	0.834[0.361]	0.424[0.515]	1.139[0.566]		3.6128[0.057]
Industry	0.42418[0.515]	1.0883[0.298]	1.115[0.573]		0.933[0.334]
Agriculture	0.7037[0.402]	0.2487[0.618]	0.5858[0.746]		6.1898[0.013]
	R^2	DW Statistic	*F*-Statistic	CUSUM	CUSUMQ
Aggregate	0.744	2.02	10.53*	Stable	Stable
Industry	0.69	1.79	11.13*	Stable	Stable
Agriculture	0.57	1.73	4.72*	Stable	Stable

*1% level of significance; **5% level of significance.
Source: Author calculation.

uses squares of the fitted values to test the functional form, and the normality test is based on the test of skewness and kurtosis of residuals. The models pass serial correlation, normality and model specification tests. However, there is evidence of heteroscedasticity in the agriculture sector model at the 5% level, but it only affects standard errors and not the elasticity estimates. White's heteroscedasticity-adjusted variances are used to deal with the problem.

5.5. Constancy of cointegration space

The estimated parameters in a time series analysis have the tendency to vary over time. We run parameter stability tests that involve estimating E.C.M. of Equation (6) and applying cumulative sum (C.U.S.U.M.) and C.U.S.U.M. of squares of recursive residuals (C.U.S.U.M.S.Q.) tests developed by Brown, Durbin, and Evans (1975). The graphs of C.U.S.U.M. and C.U.S.U.M.S.Q. are safely in the critical bounds at 5% level for aggregate, industrial and agricultural sector models.[3] According to Shahbaz et al. (2013), the stable estimates could be used for policy-making as they follow a steady pattern during the estimation period.

6. Conclusion and policy implications

The roots of the multifaceted problems faced by Pakistan's power sector can be traced back to mismanagement and planning breakdown. A lot of research is available to guide policy-makers in fixing the ailing power sector that has badly hurt the country's economic development. This study aimed to address the disagreement among researchers about the nature of electricity demand in Pakistan and its responsiveness to income and prices by revisiting the problem using load shedding-adjusted country-wide electricity data that includes K-Electric's 15% share in the electricity market. Using the A.R.D.L. method, long-run and short-run elasticities of electricity demand are estimated at aggregate and sectoral levels, except the commercial sector. The results reveal that there exists a stable long-run cointegration between electricity demand, income, price and number of customers at aggregate level and in the industrial and agriculture sectors. Evidence was not found for the commercial sector. The results suggest that economic growth would lead to higher electricity demand at aggregate level in the long run. If the current supply gap is not filled, the situation is very likely to worsen in the future. Electricity demand is more elastic with respect to income in the long run than in the short run, as determined by Narayan (2004) for Australia, and

Jamil and Ahmad (2011) and Zaman et al. (2012) for Pakistan. This implies that in the short run, adjustment in consumption pattern after price or income change is slow, but it becomes more evident in the long run.

Income-elastic electricity demand at aggregate level and in the agriculture sector, and high responsiveness of industrial electricity demand with the increase in number of customers, point towards higher electricity demand in future. This necessitates demand forecasting and capacity expansion planning accordingly to cater to future electricity demand. The government of Pakistan's Vision 2025 targets a high economic growth rate and plans to set up industrial parks under the China–Pakistan Economic Corridor project which would connect China with Gwadar sea port. The energy requirements of the economy are likely to increase manifold. The aggregate electricity demand would increase proportionally faster than G.D.P. growth in the long run. There is a need for higher investment in power generation and governance reforms in the power market to meet current and future requirements.

In the long run electricity demand is inelastic to price changes at aggregate and sectoral levels. Previous studies for Pakistan found demand to be price elastic either at aggregate and sector levels, even though there exist long hours of power cuts and the customer might be willing to pay higher prices to meet their basic electricity requirements. The results limit the importance of using electricity prices as a demand management tool. Instead, the price can be adjusted upwards to reflect the true cost of power generation. This would give government some fiscal space to invest further in electricity generation. The result is striking, and suggests that the subsidies provided to electricity consumers of all sectors could be eliminated without worrying about greatly upsetting electricity demand. Subsidies and delays in their payment to power generation companies has led to the accumulation of circular debt in the electricity supply chain, which is to a great extent responsible for power cuts in the country. The analysis implies that the electricity tariffs could be rationalised, which would significantly reduce circular debt in the cash-strapped power sector and bring some idle capacity into the system.

The elasticity estimates can be used to forecast future electricity demand with precision and in synchronisation with long-run economic growth targets to guide investment decisions in Pakistan's power market. The responsiveness of demand to income and price may vary over time, and could be sensitive to income and price levels. Future work in this area could explore time-varying income and price elasticities of electricity demand and their dynamics at very high or low income and price levels.

Notes

1. A brief summary is given in the next section in Table 1.
2. Estimates of the National Transmission and Dispatch Company.
3. The graphs are not shown here due to space constraints, but are available from the author on request.

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ORCID

Hanan Ishaque http://orcid.org/0000-0001-5004-2098

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