Electricity consumption-GDP nexus: A structural time series analysis

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ABSTRACT

This study investigates the relationships among electricity consumption, real economic activity, real price of electricity and the underlying energy demand trend UEDT at the aggregate and sectoral levels, namely, for the residential, commercial, industrial, and agricultural sectors. To achieve this goal, an electricity demand function for Pakistan is estimated by applying the structural time series technique to annual data for the period from 1972 to 2010. In addition to identifying the size and significance of the price and income elasticities, this technique also uncovers UEDT for the whole economy as well as for sub-sectors. The results suggest that the nature of the trend is not linear and deterministic but stochastic in form. The UEDT for the electricity usage of the commercial, agricultural and residential sectors shows an upward slope. This upward slope of the UEDT suggests that either energy efficient equipment has not been introduced in these sectors or any energy efficiency improvements due to technical progress is outweighed by other exogenous factors.

Keywords: Electricity; STSM; UEDT;

1. Introduction

Electricity serves an important role in both the production and consumption of goods and services within an economy. The growing populations, extensive urbanization, industrialization of economies and increasingly greater use of electrical appliances in daily life have contributed to an increase in the demand for electricity throughout the whole economy. As electricity consumption is considered an indicator of socio-economic development along with its role in the production function, the casual relationship between electricity consumption and economic growth has long been a popular topic for research.

In the last three decades, numerous studies have focused on the direction of causality between electricity consumption and economic growth, but the results remain inconclusive. The previous literature concerning the causal relationship between electricity consumption and economic growth has four broad strands. The first strand argues that unidirectional causality runs from electricity consumption to economic growth, which is known as the growth hypothesis. The second strand argues that unidirectional causality runs from economic growth to electricity consumption, which is known as the conservation hypothesis. The third strand argues that bi-directional causality exists between economic growth and electricity consumption, which is known as the feedback hypothesis. Finally, the fourth strand argues that no causal relationships exist between economic growth and electricity consumption, which is known as the neutrality hypothesis.

Recent studies (for example, Hunt et. al, 2003a, 2003b; Hunt and Ninomiya, 2003; Dimitropoulose et. al., 2005; Dilaver and Hunt, 2011) provide a number of reasons for the conflicting results of previous studies regarding the relationship between electricity consumption and economic growth. According to these recent studies, the traditional electricity demand model is based on only observable factors, such as economic activity and electricity price, and it ignores the unobservable factors. Electricity consumption also depends on unobservable factors, such as energy efficiency, technological progress and consumer preference. As electricity demand is considered to be a derived demand, electricity demand is dependent upon the efficiency of electricity appliances and capital stock. Accordingly, these studies argue that for electricity demand modeling, in addition to economic variables such as income and price, other exogenous factors (for example, trends in energy efficiency, technological progress and consumer preference) should be incorporated. Hunt et al. (2003b) argue that it is unrealistic to capture the impact of unobservable factors through a simple time trend.

Hunt et al. (2003a, 2003b), Hunt and Ninomiya (2003), Dimitropoulose et al. (2005) and Dilaver and Hunt (2011) argue that the structural time series modeling (STSM) approach developed by Harvey (1989, 1997) is the appropriate methodology to efficiently capture the effect of unobservable factors (trends in energy efficiency, technological progress and consumer preference). In the STSM methodology, time series are decomposed into unobserved trends and other irregular components, and these unobservable components are then allowed to vary stochastically. Accordingly, the stochastic trend, which is also known as the underlying energy demand trend (UEDT), captures not only exogenous technical progress but also other important socio-economic impacts, such as consumer preferences and energy saving technical changes (Hunt and Ninomiya, 2003). Hunt and Ninomiya (2003) investigate transportation oil demands for the UK and Japan by using the STSM with quarterly data for the period from 1971 to 1997, testing their results against conventional deterministic trends and arguing that the stochastic trend from the STSM is more appropriate than is the deterministic trend.

Pakistan has been facing a severe power crisis for the last few years, and the average short fall in the supply demand gap is between 5000 and 6000 MW (Economic Survey of Pakistan, 2010). While the power crisis is not a recent phenomenon in Pakistan, it is considered to be the worst power crisis in its history. Fast growing demand, rising population, inadequate power generation capacity, circular debt, high system losses due to inadequate infrastructure and corruption, fuel supply limitations due to high oil prices, and seasonal reductions in the availability of hydropower are some of the most important contributory factors to the recent power crisis in Pakistan. The resulting power cuts in the form of load shedding and price hiking of electricity are the main factors hampering the economy. The shortage of electricity is forcing the industrial sector to work at below normal production levels, threatening export performance, and creating social unrest in the country. To design an effective power policy, it is important for policy makers to understand the relationships among electricity demand, economic growth and other unobservable factors.

The purpose of this study is to investigate the relationships among Pakistan's electricity consumption, real economic activity, real price of electricity and the UEDT at the aggregate and sectoral levels. To achieve this goal, the STSM approach is applied in this paper for the whole economy and for the residential, commercial, industrial and agricultural sectors.

The numerous previous studies that have focused on the electricity demand in Pakistan present conflicting results. These studies did not model the UEDT to capture the effect of unobservable factors on Pakistan's electricity demand. This limitation may be one of the more important reasons for the conflicting results of these studies. Therefore, the motivation for this study is twofold. First, the modern approach of structural time series modeling (STSM) is used, enabling us to focus on the economic and exogenous factors of the electricity demand in Pakistan. To the best of this researcher’s knowledge, this is the first study that investigates the relationships among electricity consumption, real price of electricity, real economic activities and the stochastic underlying energy demand trend (UEDT) for Pakistan. Second, for the whole economy and for some sectors, interventions (level, irregular and slope) were introduced into the analysis according to data requirements.

The remainder of this paper is organized as follows. Section 2 briefly reviews the previous studies related to electricity demand in Pakistan. Section 3 presents the data and the econometric methodology applied in this research. Section 4 presents the empirical results, and Section 5 provides a conclusion.

2. Previous electricity demand studies for Pakistan

Some important previous studies on electricity demand with respect to Pakistan include Masih and Masih (1996), Lee (2005), Siddique (2004), Aqeel and Butt (2001), Jamil and Ahmed (2010), and Kahan and Qayyum (2009), among others. These studies mainly used causality tests and co-integration techniques and attempted to identify the causal relationship between electricity consumption and economic growth. Masih and Masih (1996) and Lee (2005) explore the causality runs from energy consumption to GDP in the short-run and the long-run and conclude that a shortage of energy may harm economic growth in Pakistan. Aqeel and Butt (2001) use the co-integration technique and Hsiao's version of the Granger causality test with annual data from 1956 to 1996 and find the causality runs from electricity consumption to economic growth at the aggregate level without feedback. Siddique (2004) applies Hsiao's Granger causality test and finds that growth in capital stock, electricity consumption and petroleum products significantly affects economic growth. Jamil and Ahmed (2010) employ the co-integration technique and VECM with annual data from 1960 to 2008 to explore the direction of causality among electricity consumption, real economic activity and electricity prices at the aggregate and disaggregate levels and find unidirectional causality from real activity to electricity consumption at the aggregate and sectoral levels. They also find that long-run income elasticity is significant and above unity for electricity consumption in the aggregate, residential, commercial, and agricultural sectors, while price elasticity is greater than unity (in absolute terms) only for the commercial sector. As the results from these studies are mixed, the general conclusion from previous studies regarding Pakistan's electricity consumption and the economic growth nexus is that there is no consensus on the direction of causality between electricity consumption and economic growth. Table 1 reports the results of some of the recent studies.

Table 1: Some selected studies

Authors	Variables	Methodology	Country & period	Findings
Jamil and Ahmad (2010)	GDP, electricity price, electricity consumption	Johansen co-integration, VECM Granger causality	Pakistan 1960-2008	GDP causes EC[a]. Growth in output in commercial, manufacturing and agricultural sectors tend to increase EC
Aqeel and Butt (2001)	Per capita GDP, per capita energy, gas, electricity, & petroleum consumption	Co-integration test Hsiao's version of Grange causality	Pakistan 1956-1996	GDP causes energy consumption GDP causes petroleum consumption EC causes GDP No causality in gas consumption and GDP
Mehrara (2007)	GDP per capita, energy consumption per capita	Panel co-integration, panel Granger causality	Oil exporting countries 1971-2002	Unidirectional causality from economic growth to energy consumption
Narayan and Smyth (2005)	EC, GDP, index of employment	Co-integration, and Granger causality	Australia 1966-1999	All variables are co-integrated GDP and employment cause EC
Chen et.al (2007)	GDP, EC	Panel co-integration, and Granger causality test	10 Asian Countries 1971-2001	Unidirectional short-run causality from economic growth to EC. Long-run causality between economic growth and EC.
Ghosh (2002)	GDP, electricity consumption	Engel-Granger Granger causality	India 1950-1997	No co-integration Unidirectional causality from EC to GDP
Shiu and Lam (2004)	Real GDP electricity Consumption	Johansen co-integration	China 1971-2000	EC causes GDP
Morimoto and Hope (2004)	Real GDP, electricity production	Granger causality	Sri Lanka 1960-1998	Electricity production causes GDP
Kouakou (2011)	GDP and EC	ARDL Granger causality	Cote d'Ivoir 1971-2008	Bidirectional causality between EC and GDP Unidirectional causality running from EC to industry value added in the short-run.
Gurgul and Lach 2012	EC and GDP, and employment	Linear and non Linear Granger causality	Poland 2000q1-2009q4	Feedback between total EC and GDP as well as between total EC and employment. Unidirectional causality running from industrial EC to employment

a: EC denotes the electricity consumption

3. Methodology and data

The structural time series model consists of a stochastic trend component and an irregular term (Harvey et al., 2005). This approach consists of subdividing the dependent variable into explanatory variables and including recurrent and irregular components. The STSM allows for the estimation of a nonlinear UEDT that can be negative, positive or zero over the estimation period; however, simple deterministic time trends are not ruled out in the STSM methodology (Harvey and Shephard, 1993; Durbin and Koopman, 2001; Harvey and Proietti, 2005; Dilaver and Hunt, 2011). The structural time series model has the following advantages over other time series methodologies (Koopman, 1992):

a. The STSM provides the most satisfactory framework for analyzing time series because it does not rely on subjective judgments;
b. It provides a full set of different diagnostic tools to validate the estimated model and is correlated to the various econometric methodologies of modeling; and
c. Most significantly, the structural time series model is preferable because it provides a direct approach to the interpretation of unobserved components in a time series. (Koopman, 1992, p.1)

3.1 The structural time series model (STSM)

The STSM approach allows for a determination of the unobservable trend and irregular component that are permitted to vary stochastically over time. Consider the following model, as described by Hunt et al. (2003):

$$E_t = \mu_t + \beta_1 Y_t + \beta_2 P_t + \varepsilon_t \quad (1)$$

where E_t represents the electricity consumption at the aggregate and sectoral levels measured in gigawatt hours (GWh); Y_t represents the real economic activity variable for the appropriate sector; P_t represents the real price for each corresponding sector; μ_t represents the underlying energy demand trend (UEDT) component for electricity demand in Pakistan; and ε_t is the irregular component.

Trend Component

The UEDT component, μ_t, is assumed to have the following stochastic process:

$$\mu_t = \mu_{t-1} + \beta_{t-1} + \eta_t \qquad \eta_t \sim NID(0, \sigma_\eta^2) \qquad (2)$$

$$\beta_t = \beta_{t-1} + \xi_t \qquad \xi_t \sim NID(0, \sigma_\xi^2) \qquad (3)$$

Equations (2) and (3) represent the level and slope of the trend, respectively.

η_t and ξ_t are the mutually uncorrelated white noise disturbances with zero means and variances σ_η^2 and σ_ξ^2, respectively. Larger variances cause greater stochastic movements in the trend, σ_η^2 allows the level of trend to shift up and down, and σ_ξ^2 allows the slope to change (Harvey and Shephard, 1993). The shape of the underlying demand trend is determined by these hyper-parameters, including σ_ε^2 , σ_η^2 and σ_ξ^2. The hyper-parameters and other parameters of the model are estimated by a combination of maximum likelihood and the Kalman filter. Residuals of the equation and a set of auxiliary residuals are also estimated to evaluate the model. The auxiliary residuals consist of smoothed estimates of model disturbances (irregular residuals), smoothed estimates of the level disturbances (level residuals), and smoothed estimates of the slope disturbances (slope residuals).

Irregular slope and level interventions maintain the normality of the auxiliary residual (Harvey and Koopman, 1992). These interventions generally yield information regarding important breaks and structural changes at certain dates during the estimation period. The irregular intervention can be described as a pulse effect because it has only a temporary effect on the UEDT. It is, therefore, a short-run response, which is normally used to account for an unexpected event or a market shock. However, level and slope interventions do have a permanent effect on the estimated UEDT; thus, these effects are longer lasting.

3.2. ARDL model with a stochastic trend

For the econometric estimation, the dynamic autoregressive distributed lag model (ARDL) specification is utilized as follows:

$$A(L)E_t = B(L)Y_t + C(L)P_t + \mu_t + \varepsilon_t \qquad (4)$$

where A(L) is the polynomial lag operator $1 - \lambda_1 L - \lambda_2 L^2$; B(L) is the polynomial lag operator $1 + \varphi_1 L + \varphi_2 L^2$; and C(L) is polynomial lag operator $1 + \theta_1 L + \theta_2 L^2$. All the variables are transformed in natural logarithmic form. $B(L)/A(L)$ is the long-run income elasticity, $C(L)/A(L)$ is the long-run price elasticity, μ_t represents the underlying demand trend as defined herein, and ε_t is a random error term.

We used annual data from 1972 to 2010 for the empirical analysis. The electricity consumption (E_t) data in gigawatt hour (GWh) and the average real price (P_t) data for the whole economy, the residential sector, commercial sector, industrial sector and agricultural sector are obtained from various issues of the Pakistan Energy Year Book. The real GDP (Y_t) data for the whole economy, the commercial sector, industrial sector and agricultural sector are obtained from various issues of the Economic Survey of Pakistan. Private consumption expenditure is used as a proxy for real economic activity in the residential sector.

4. Empirical results

Equation (4) estimates electricity consumption for the whole economy, the residential sector, the commercial sector, the industrial sector and the agricultural sector of Pakistan. Initially, we select two lags on the basis of the Akaike information criterion (AIC), and after deleting the insignificant variables from the model and including the interventions (slope for 1994, irregular for 1999 and level for 2009), the final estimation results for each sector are presented in Table 2. The preferred model passes all the diagnostic tests for residuals and the auxiliary residuals and the prediction tests for 2002 through 2010. Diagnostic tests are presented in Table 3.

Table 2 : Electricity Demand (STSM Approach)					
Estimated Coefficients	Whole Economy	Residential	Commercial	Industrial	Agricultural
Y_t	1.45 (9.21)	0.21 (2.23)	0.20 (2.08)	0.55 (6.21)	0.44(2.50)
Y_{t-1}				0.22 (2.39)	
Y_{t-2}	0.43 (5.04)			0.40 (4.17)	
P_t		-0.07 (-1.52)	-0.16 (-3.54)	0.21(3.95)	0.04 (1.12)
P_{t-1}	-0.08 (-2.28)		-0.10 (-2.52)		
Long-run Elasticities					
Income (Y)	1.88	0.21	0.20	1.17	0.44
Price (p)	-0.08	-0.07	-0.26	0.21	0.04
Estimated hyper-parameters					
σ_ξ^2 x10^{-4}	6.42	1.69	2.52	1.03	0.00
σ_η^2 x10^{-4}	0.00	0.00	0.00	0.00	2.21
Nature of Trend	Smooth trend model	Smooth trend model	Smooth trend model	Smooth trend model	Local level model with drift
Diagnostics					
Standard Error	0.02	0.03	0.02	0.03	0.04
Normality	3.67	0.09	0.64	2.16	0.62
Kurtosis	0.56	0.42	0.55	0.63	0.02
Skewness	0.27	0.05	0.28	1.53	0.00
H(9)	1.81	0.91	1.69	1.11	0.81
r(1)	-0.16	-0.01	-0.11	-0.07	0.06
r(6)	-0.08	-0.07	-0.19	-0.05	-0.30
DW	1.89	1.92	2.12	1.88	1.83
Q (6, 4)	4.21	4.80	4.38	2.10	7.95
R^2	0.85	0.78	0.97	0.74	0.89

Normality (corrected for Bowman-Shenton), kurtosis and skewness are error normality statistics.
Normality is distributed as $\chi^2(2)$, and kurtosis and skewness are distributed as $\chi^2(1)$.
H(9) is the test of heteroscedasticity, approximately distributed as F(9,9).
DW is Durbin Watson statistic for first-order autocorrelation;
r(1) and r(6) are the serial correlation coefficients at the 1st and 6th lags, respectively.
Q(6,4) is the Box-Ljung statistic distributed as χ^2.

The LR test represents a likelihood ratio test and is used to determine the deterministic time trend. The nature of the trend is a local level model with drift.
Prediction error variance (p.e.v.), prediction error mean deviation (p.e.v./m.d.^{2}), and the coefficients of determination (R^2, Rd^2) are all measures of the quality of fit.

Table 3: Auxiliary residuals

	Whole Economy	Residential	Commercial	Industrial	Agricultural
Irregular					
Normality	0.03	0.62	1.98	0.75	1.25
Kurtosis	0.02	0.45	1.97	0.63	1.25
Skewness	0.01	0.16	0.005	0.12	0.006
Level					
Normality	N/A	N/A	N/A	N/A	0.14
Kurtosis	N/A	N/A	N/A	N/A	0.07
Skewness	N/A	N/A	N/A	N/A	0.07
Slope					
Normality	0.12	0.69	1.74	0.44	N/A
Kurtosis	0.01	0.36	0.84	0.19	N/A
Skewness	0.11	0.33	0.90	0.25	N/A
Predictive test	6.69	9.13	15.88	10.99	6.6
Cusum t	0.36	0.39	0.48	0.34	0.95
LR test	113.61	112.35	93.50	105.01	84.66

Normality (corrected for Bowman-Shenton), kurtosis and skewness are error normality statistics.
Normality is distributed as $\chi^2(2)$, and kurtosis and skewness are distributed as $\chi^2(1)$.
The LR test represents a likelihood ratio test and is used to determine the deterministic time trend. The nature of the trend is a local level model with drift.
Prediction error variance (p.e.v.), prediction error mean deviation (p.e.v./m.d.^{2}), and the coefficients of determination (R^2, Rd^2) are all measures of the quality of fit.

As shown in the results reported in Table 2, the sum of the long-run price elasticities of all four sub- sectors is equal to the long-run price elasticity of the aggregate economy, and similarly, the sum of the long-run income elasticities of all four sub-sectors is approximately equal to the long-run income elasticity of the aggregate economy. The low price elasticity of electricity demand reflects the weak link between the price of electricity and the demand for electricity, which creates problems for demand management. This result implies that the demand does not react to changes in price, as there are limited or no options for consumer to switch from electricity to other sources of energy in response to the price of electricity.

4.1. Whole economy

The LR test for the whole economy, as displayed in Table 3, does not reject the stochastic specification of the UEDT in the data. The UEDT has a fixed level and stochastic slope. Thus, the form of the UEDT is a smooth trend model. The estimated UEDT in Fig. 1 slightly increases in the early 1980s and then falls continuously after 1985 but not at a fixed rate, as is assumed in a deterministic model. The downward shape of the estimated UEDT suggests that aggregate electricity demand for the whole economy is decreasing at an increasing rate. This result implies that the aggregate electricity demand for the whole economy declined continuously after 1985, and as a result, trying to approximate the UEDT by a linear time trend or an intercept term is not appropriate. The downward shape of the UEDT probably reflects the implementation of energy efficient improvements due to technical progress during the time period.

The long-run income and price elasticities for aggregate electricity demand for the whole economy are 1.88 and -0.08, respectively. The long-run income elasticity is slightly higher than the 1.70 estimated by Jamil and Ahmad (2010), and the long-run price elasticity is much lower than their estimate of -0.83 (in absolute terms). Hunt et al. (2003) argue that these differences in the elasticities are due to the declining shape of the UEDT. When the UEDT is downward sloping, it is expected that the conventional model underestimates the income elasticity with increasing income and over estimates the price elasticity (in absolute terms) with an increasing price (Hunt et al., 2003).

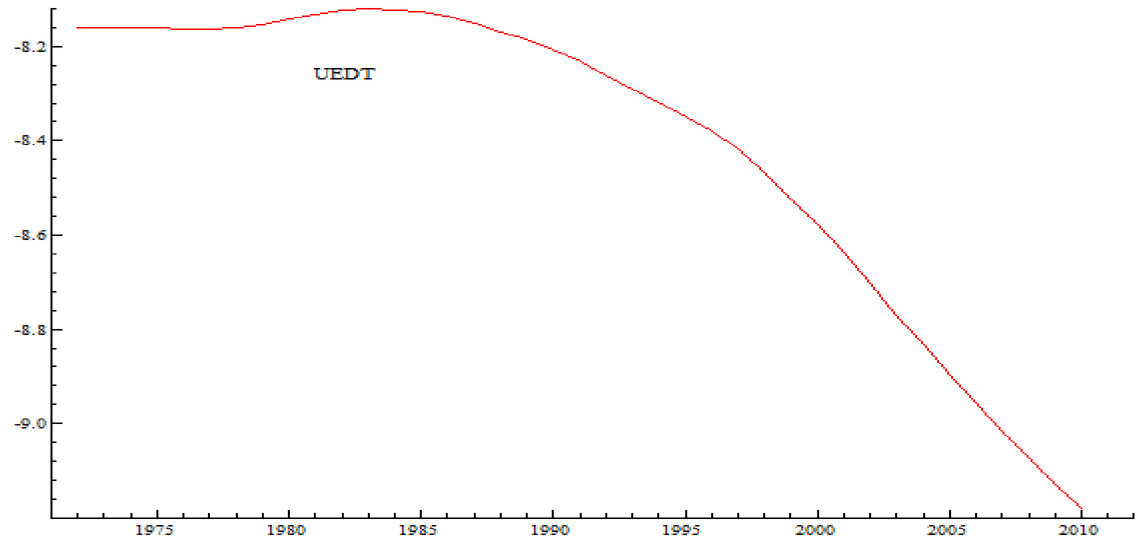

Fig.1. Estimated UEDT for electricity demand for whole economy of Pakistan

4.2. Residential sector

The estimated model for the residential sector does not include a dynamic term, suggesting that the residential electricity demand adjusts instantaneously to the long-run position. The estimated long-run income and price elasticity are 0.21 and -0.07, respectively. The lack of a relationships between electricity consumption and price indicate that demand is relatively inelastic to price. Furthermore, the LR test does not reject the stochastic formulation of the trend for residential electricity demand for Pakistan. The chosen model is the smooth trend model with a fixed level and stochastic slope.

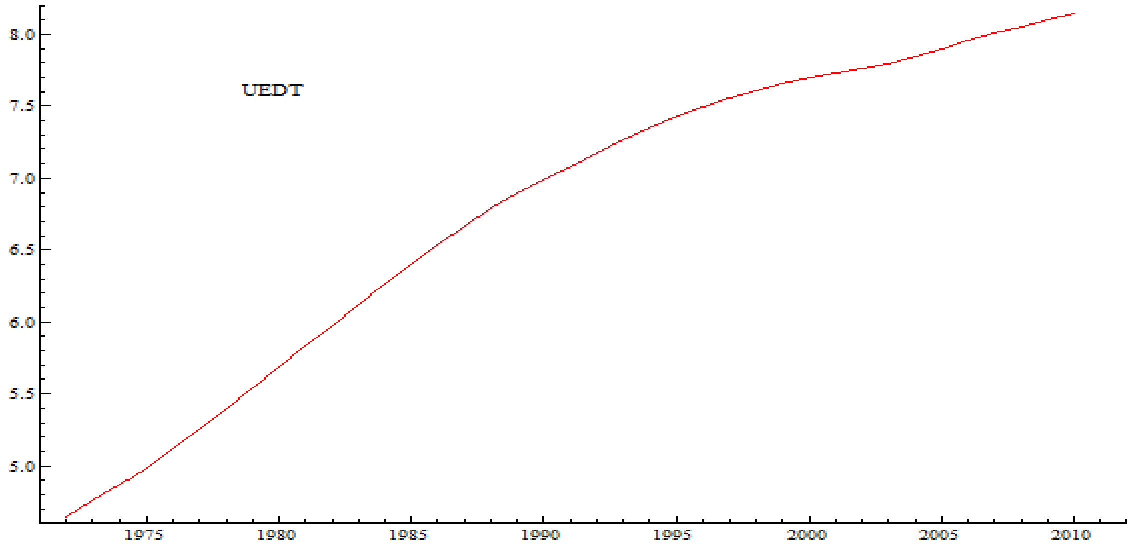

Fig. 2. Estimated UEDT for residential electricity demand

The shape of the estimated UEDT (illustrated in Fig. 2) increases but not at a fixed rate, which might imply that there are no or few alternative options available to the consumer in response to the changes in the price of electricity. For the most part, electricity in Pakistan is used for cooling rather than for heating and cooking, and people do not substantially change the stock of electric appliances in response to increases in the price of electricity due to the limited degree of substitutability. In low income countries, consumers are unwilling to replace relatively expensive items, such as refrigerators, computers and air conditioners, in response to the high cost of electricity. Other exogenous factors that probably contribute to the upward UEDT shape are the large increases in air conditioning loads and the growing number of customers. The number of electricity consumers in residential sectors has increased over the years due to the rapid expansion in the supply of electricity to villages between 1996 and 2010, as a 112 percent growth was observed in residential consumers of electricity (Pakistan Economic Survey, 2010).

4.3. Commercial sector

The LR test for the commercial sector does not reject the stochastic specification of the UEDT in the data. The UEDT has a fixed level and stochastic slope; therefore, the form of the UEDT is a smooth trend model. The estimated long-run income and price elasticity are 0.20 and -0.26, respectively. The UEDT for the commercial sector's electricity usage shows an upward trend over the whole period, but it is not at a fixed rate (illustrated in Fig. 3).

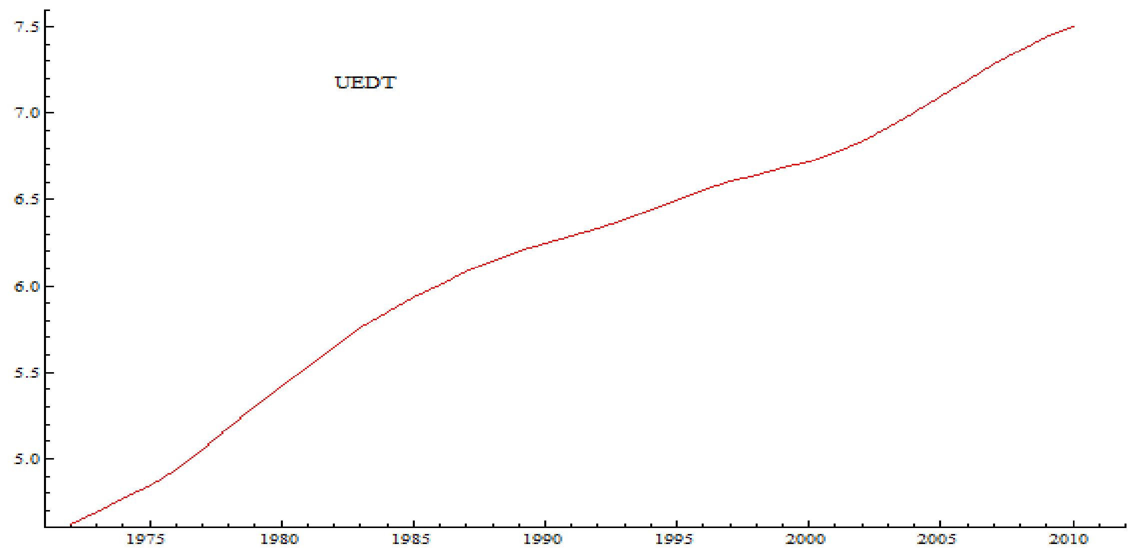

Fig. 3. Estimated UEDT for commercial electricity demand

These results suggest that the changes and shifts in energy use due to the introduction of more energy efficient appliances are outweighed by other exogenous factors. The growing demand of electricity by the commercial sector and the limited availability of alternate source of energy in most commercial businesses are important factors that probably contribute to the upward trend. According to the Pakistan Economic Survey, from 1996 to 2010, an approximate 77 percent growth was recorded in the number of electricity consumers by the commercial sector.

4.4. Industrial Sector

The estimated long-run income and price elasticities are 1.17 and 0.21, respectively. It is worth noting that income elasticity for the industrial sector is greater than 1 and income elasticities for all other sub-sectors are between 0.20 and 0.44. The price elasticity of the industrial electricity demand reflects the close link between output and electricity demand in the industrial sector (Hunt et al., 2003).

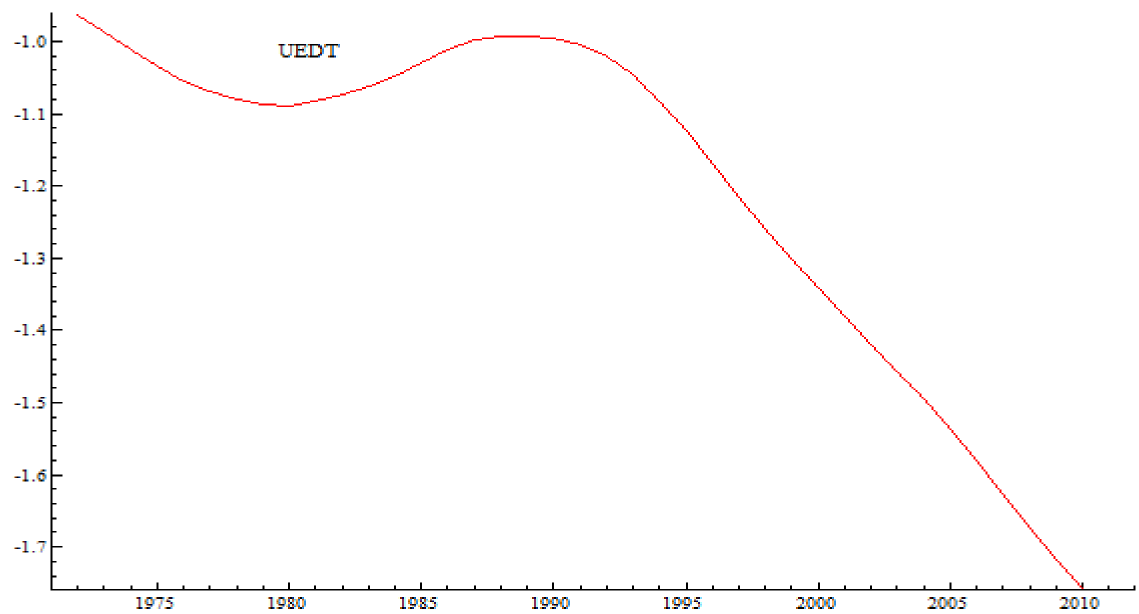

Fig. 4. Estimated UEDT for industrial electricity demand

The LR test supports the stochastic formulation and trend over the deterministic nature of the trend. The UEDT has a fixed level and stochastic slope, and thus, the form of the UEDT is a smooth trend model. The estimated UEDT (illustrated in Fig. 4) slightly declines in the 1970s, increases in the 1980s, and then begins a continuous fall in 1990. The cubic shape of the estimated UEDT reflects the structural changes in Pakistan's economy throughout the period. The initial decline followed by an increase the UEDT may reveal the decline in industrial production due to the nationalization program of the government of that time and then the reversal in policy by the next government. The downward shape of the estimated UEDT after the second half of the 1980s shows the industrial sector's electricity demand behavior. The downward shape of the UEDT probably reflects the use of energy efficient appliances and alternate sources of energy such as oil and gas.

4.5. Agricultural Sector

The preferred model for the agricultural sector does not include any lagged variables, thus implying an immediate adjustment to the long-run position. The LR test does not reject the stochastic formulation of the UEDT, which has a stochastic level and fixed slope. Accordingly, the form of the UEDT is at a local level with drift. The estimated UEDT is upward sloping with some fluctuation, as illustrated in Fig. 5.

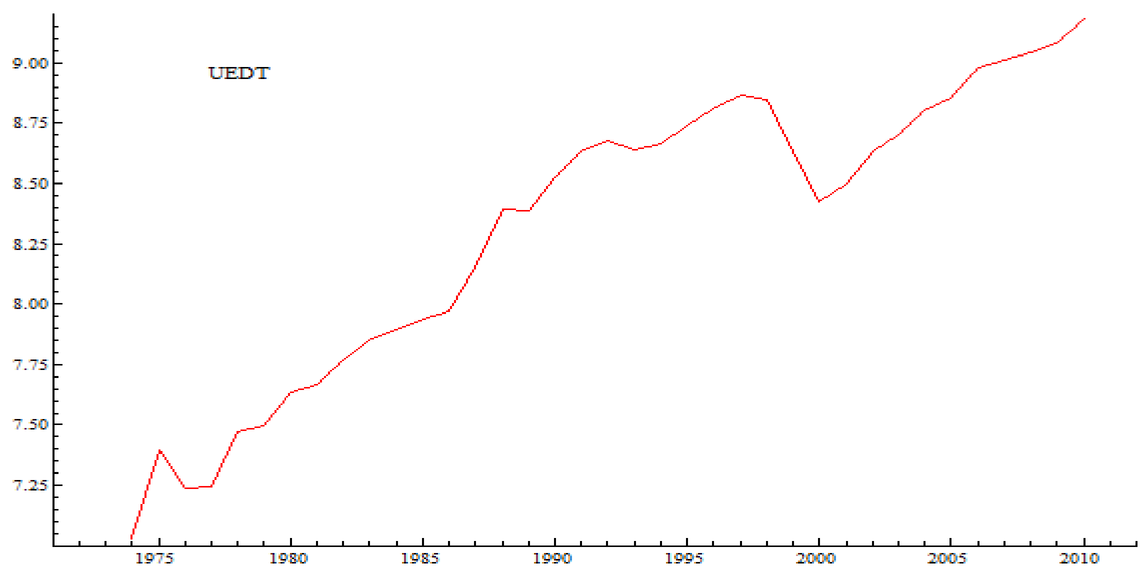

Fig.5. Estimated UEDT for agricultural electricity demand

One important factor that probably contributes to this upward trend is the use of ground water for irrigation pumped through tube wells in Pakistan, as groundwater use has risen exponentially for the last three decades (Pakistan Economic Survey), thus increasing the burden on Pakistan's electricity demand.

The estimated long-run income and price elasticity are 0.44 and 0.04, respectively. These results imply that there is a positive relation between agricultural productivity and electricity consumption by the agricultural sector. Price elasticity is also positive but statistically insignificant. This lack of significance may be because the agricultural sector of Pakistan consumes highly subsidized electricity.

5. Conclusion

The current level of electricity supply in Pakistan is deemed inefficient due, in part, to a lack of infrastructure. Blackouts, which are rampant in the country, have extremely adverse effects not only for the economic development of the country but also for the social life of people in Pakistan.

This paper investigates the relationships among electricity consumption, real economic activity, electricity prices and the UEDT at the aggregate and sectoral levels, namely, for the residential, commercial, industrial, and agricultural sectors. To achieve this goal, an electricity demand function for Pakistan is estimated by applying the structural time series technique to annual data over the period from 1972 to 2010. In addition to identifying the size and significance of the price and income elasticities, this technique also uncovers the electricity underlying energy demand trend (UEDT) for the whole economy as well as for sub-sectors. The results suggest that the nature of the trend is not linear and deterministic but stochastic in form. The UEDT for the electricity usage of the commercial, agricultural and residential sectors showed an upward slope for the whole period. This upward slope of the UEDT suggests that either energy efficient equipment has not been introduced in these sectors or that any energy efficiency improvement due to technical progress is outweighed by other exogenous factors. For example, the agricultural sector, which is the third largest consumer of electricity in Pakistan, uses ground water for irrigation that is pumped through tubewells. These tubewell pump sets are generally inefficient and outdated. The government should help farmers to replace the highly inefficient, outdated and energy-consuming equipment with reliable, energy-efficient equipment.

The results further suggest that the electricity demand may not be managed through pricing mechanisms. The low price elasticity of demand for the whole economy and for the residential sector indicates that demand did not react to changes in price. It seems that there are limited or no options for consumers to switch from electricity to other sources of energy in response to electricity prices. On the supply side, in 2003, 48.5 percent of the electricity was generated from gas; 15.7 percent, from oil; and the remaining 35.8 percent, from hydroelectric and nuclear sources (World Development Indicator, 2012). However, in 2009, 29.4 percent of the electricity was generated from gas and 38 percent from oil, which means that Pakistan moved from gas, which is a relatively low cost and environmentally friendly source of electricity generation, to oil, which, in addition to being an expensive means of electricity generation, produces a considerable amount of pollution. The increased costs associated with generating electricity have forced the government to increase the price of electricity, and because of the low price elasticity, the demand may not be managed through price mechanisms. As a consequence, high electricity prices may encourage power theft.

The government should focus on policies that ensure the smooth and sustainable supply of electricity for the economy. To increase the electricity supply, there is a need to revitalize the existing infrastructure, as there are highly inefficient plants that have outlived their useful life. Furthermore, the private sector may be involved through competitive bidding to replace these outdated plants with new ones.

In the long-run, the government of Pakistan should focus its attention on hydroelectricity generation because the potential capacity of hydroelectricity is abundant in the country. Hydroelectricity is characterized by low variable costs and is environmentally friendly in comparison to thermal and nuclear power.

References

Aqeel,A., Butt, M.S., 2001.The relationship between energy consumption and economic growth. Asia Pacific Development Journal 8,101-110.

Chen, S.T., Kuo, H.I., Chen, C.C.,2007. The relationship between GDP and electricity consumption in 10 Asian countries. Energy Policy 35, 2611-2621.

Dilaver, Z., Lester, C.H., 2011. Industrial electricity demand for Turkey: A structural time series analysis. Energy Economics, 33, pp. 426-436.

Dimitropoulos, J., Hunt, L.C., Judge, G., 2005. Estimating underlying energy demand trends using UK annual data. Applied Economics Letters 12, 239–244.

Durbin, J., Koopman, S.J., 2001. Time series analysis by state space methods. Oxford University Press, Oxford.

Ghosh,S., 2002. Electricity consumption and economic growth in India. Energy Policy 30,125-129.

Gurgul, H., Lach, L., 2012. The electricity consumption versus economic growth of the Polish economy. Energy Economics 34, 500-510.

Harvey, A.C., 1997. Trends, cycles and auto regressions. Economic Journal, 107, 192-201

Harvey, A.C.,1989. Forecasting, structural time series model and kalman filter. Cambridge University press. Cambridge.

Harvey, A.C., Koopman, S.J., 1992. Diagnostic checking of unobserved-components time series models. J. Bus. Econ. Stat. 10, 377–389

Harvey, A.C., Proietti, T., 2005. Readings in unobservable component models. Oxford University Press, Oxford.

Harvey, A.C., Shephard, N.,1993. Structural time series models. In: Maddala, G.S., Rao, C.R., Vinod, H.D. (Eds.), Handbook of Statistics, vol. 11. North Holland, Amsterdam, pp. 261–302.

Harvey, A.C., Koopman, S.J., Shephard, N., 2005. State space and unobserved component models: theory and applications. Cambridge University Press, Cambridge.

Hunt, L.C., Judge, G., Ninomiya, Y., 2003a. Modelling underlying energy demand trends chapter 9. In: Hunt, L.C. (Ed.), Energy in Competitive Market: Essays in Honour of Colin Robinson. Edward Elgar, UK, pp. 140–174.

Hunt, L.C., Judge, G., Ninomiya, Y., 2003b. Underlying trends and seasonality in UK energy demand: a sectoral analysis. Energy Economics 25, 93–118.

Hunt, L.C., Ninomiya, Y., 2003. Unravelling trends and seasonality: a structural time series analysis of transport oil demand in the UK and Japan. The Energy Journal 24-3, 63–69.

Jamil, F., Ahmad, A.,2010. The relationship between electricity consumption, electricity price and GDP in Pakistan, Energy policy 38, pp, 6016-6025.

Khan, M. A., Qayyum, A.,2009. The demand for electricity in Pakistan. OPEC Energy Review 33: 70–96. doi: 10.1111/j.1753-0237.2009.00158.x

Koopman, S.J.,1992. Diagnostic checking and intra-daily effects in time series models, Doctoral Thesis, Tinbergen Institute research series, 27

Kouakou, A.K., 2011. Economic growth and electricity consumption in Cote d'Ivoire: evidence from time series analysis. Energy Policy 39, 3638-3644.

Lee. C., 2005. Energy consumption and GDP in develpoing countries: a co-integrated panel analysis. Energy Economics 27, 415-427.

Masih, A.M., Masih, R., 1996. Energy consumption, real income and temporal causality: results from a multi-country study based on cointegration and error correction modeling techniques. Energy Economics 18, 165-183.

Mehrara, M., 2007. Energy consumption and economic growth: The case of oil exporting countries. Energy Policy 35, 2939-2945.

Morimoto, R., Hope,C., 2004.The impact of electricity supply on economic growth in SriLanka. Energy Economic 26, 77-85.

Narayan, P.K., Smyth, R., 2005. Electricity consumption, employment and real income in Australia: evidence from multivariate Granger casualty test. Energy Policy 33, 1109-1116.

Shiu, A., Lam, P., 2004. Electricity consumption and economic growth in China. Energy Policy 32,47-54.

Siddiqui, R., 2004. Energy and Economic Growth in Pakistan, the Pakistan Development Review, 42:2, pp. 175-200