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Examining Relationship between Electricity Consumption and its Major Determinants in Pakistan

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ABSTRACT

The objective of the study is to examine the relationship between electricity consumption and its major determinants; particularly economic growth, number of electricity customers, electricity prices and electricity shortages in Pakistan using time series data from 1972 to 2012. The study employed the Johansen co-integration test to examine relationship between electricity consumption and its determinants. Multivariate granger causality test is then applied to determine the causality direction between electricity consumption and its major determinants. The results reveal that determinants of electricity consumption function are cointegrated and economic growth, number of electricity customers are positively related to electricity consumption, while electricity price and electricity shortages are negatively related to electricity consumption in Pakistan. However, bidirectional causality found between electricity consumption, economic growth and electricity customers except electricity prices which is exogenous determined. The short-run, long-run elasticities and multivariate granger causality results implies that at different time frame there is need to implement different policies for Pakistan. There is need to revise electricity pricing policy and find alternative renewable sources to generate low cost electricity and further need to enhance energy management expertise to cope with crises in an efficient way.

Keywords: Electricity Consumption, Economic Growth, Electricity Customers, Pakistan
JEL Classifications: Q4, Q43

1. INTRODUCTION

Throughout the world the most widely used and desirable form of energy is electricity. Electricity consumption is more intensive in industrial based economies. Over past few decades technology explosion has taken place and all this takes electricity as an essential input to carry out the work. Among all energy resources electricity has been of prime importance as it is being generated, stored and transmitted to longer distances very easily.

Payne (2010) advocated that electricity plays a crucial role in the production and evident that there is a strong relationship between electricity consumption and economic growth. Pao (2009) also acknowledged that electricity is the most flexible form of energy and constitutes one of the dynamic infra-structural inputs in socioeconomic growth.

Over the past decades researchers had extensively examined the relationship between electricity consumption and economic growth. Nevertheless, the causality direction between electricity consumption and economic growth remains contrary. Elasticity estimates have particular significance for designing pricing policies because it properly set energy prices that imitate their true cost minimize behavioral distortions and uneconomic fuel substitutions.

In this framework, up to date estimates of price and income elasticities would be very valuable. This research studied electricity consumption rather than the energy consumption which has been investigated in the voluminous literature. This study examines the relationship between electricity consumption and its major determinants like gross domestic product (*GDP*), number of customers, electricity price and electricity shortages in Pakistan for the period of 1972-2012.

Pakistan had already installed capacity of 60 MW at the time of independence in 1947 for a population of 31.5 million. Exactly 12 years later Water and Power Development Authority (WAPDA) was established in 1959 and capacity raise up to 119 MW. By the year 1965 electricity generation capacity was increased up to 636 MW and power generation to 2500 million kWh. In this era, the fastest rate of economic development was observed in every sector either industrial or agricultural and a change was observed in living standard.

Up till 1970 new hydel and thermal power plants were installed and pace of development increased and in very next 5 years generating capacity rose to 1331 MW. In 1980 capacity was 3000 MW, which rose up to 7000 MW within an year. In Karachi a huge demand rate was observed during these years, industrial and commercial houses were set up leading to an unexpected boost in demand for electricity. So, the license was issued to Karachi Electric Supply Company (KESC) to generate, transmit and distribute electricity in its licensed area.

In 1998, Pakistan's power structure was restructured and modified in accordance with demand rate and economic development. Before 1998, KESC served in Karachi and the rest of the country served by WAPDA. Laterally, WAPDA structured into 4 generating companies (GENCO's), 10 distributing companies (DISCO's) and one transmission company National Transmission and Dispatch Company (NTDC). KESC generates, purchase electricity from NTDC, Independent Power Plants (IPP's) to meet demand.

WAPDA, IPPs, RPPs and GENCOs sell electricity to the Central Power Purchasing Agency (CPPA) - NTDC. NTDC through CPPA, transmits the electricity to distribution companies (DISCOs). KESC is the only vertically integrated electricity company in Pakistan. It has its own generation plants and to meet the demand of its coverage area - Mainly Karachi, KESC buys electricity from NTDC. DISCOs include Peshawar, Islamabad, Lahore, Multan, Quetta, Hyderabad, Gujranwala, Faisalabad, Sukkur, Tribal areas and Karachi electric supply company to distribute electricity to different categories of consumers for domestic, industrial, commercial, agricultural, public lighting usage. The power sector supply chain is shown in Figure 1.

Due to investment by private sector in electricity generation up to 2012, installed generation capacity of Pakistan rose up to 23246 MW, in which maximum share is of generation capacity by IPP (37%). Secondly by government owned thermal power plants (31%), thirdly by hydro power generation (29%) and in last by nuclear power generation (3%). Figure 2 presents installed generation capacity of Pakistan by source.

Electricity consumption was 4738 GWh by the year 1970, and it increased vigorously up till 2012 to 75,961 GWh. The industrial sector is largely dependent on it, and one of the most electricity consumption sector. In 1970, it consumed up to 2299 GWh, which increased to a level of 19,802.43 in 2006. Total electricity consumption rose up to 67,629.17 GWh in 2006, which is the highest level achieved and then start decreasing up till 2012.

The current electricity production in Pakistan is around 479.16 MWh whereas the electricity demand had jumped from

Figure 1: Pakistan power sector supply chain

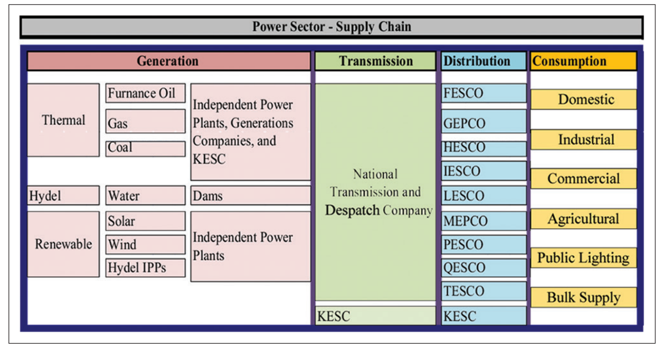
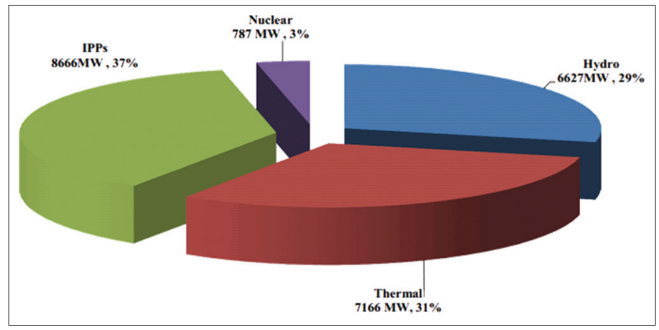


Figure 2: Installed generation capacity of Pakistan (2012)



625 to 833.33 MWh in the year 2010 (Khan and Ahmad, 2009). This massive increase in demand suggests that the forthcoming electricity crisis in Pakistan will become even more severe in the near future.

Numerous earlier studies in Pakistan recommend that energy consumption Granger-causes real output. Different researcher included Mushtaq et al. (2007), Zaman et al. (2012) and Liew et al. (2012) scrutinized the energy-growth nexus in Pakistan at the sectoral level. Specifically, Mushtaq et al. (2007) explored the relationship between electricity consumption, price of electricity and real output in the agricultural sector in Pakistan. It was found that the variables are cointegrated, but only unidirectional Granger causality running from electricity consumption to real output was detected.

In Pakistan electricity consumption has raised more than 16-fold in the course of recent four decades and expected to keep expanding quickly later on. Hence, analysis of the relationship between electricity consumption and its determinants in the country are extremely imperative and is duly urgent to the policy makers, market players and consumers. Motivated by the importance of this subject to the existing literature and policy making, this research is to investigate the relationship between electricity consumption and its major determinants in Pakistan at the aggregate level from 1972 to 2012.

2. LITERATURE REVIEW

Theoretical and empirical studies on electricity consumption and economic growth linkage are widespread partly due to the significant role of electricity in sustainable economic development. In the past two decades, various studies have been carried out to examine the relationship between electricity consumption and economic growth (Ozturk, 2010; Bouoiyour et al., 2014 for extensive review). The overall findings show that there is a strong relationship between electricity consumption and economic growth. However, researchers are unable to arrive at a consensus on the flow of causality between electricity consumption and economic growth.

In past many investigations have been carried out like for example, Ferguson et al. (2000) has studied for 100 countries and found co-integration between electricity consumption and economic growth. Relation may come out to be unidirectional or bidirectional or may neutrality hypothesis held true. Yoo (2005), Jumbe (2004), Morimoto and Hope (2004) and Yang (2000) suggests a bidirectional relation between electricity consumption and *GDP* in Korea, Bangladesh, Taiwan etc. Filippini and Pachauri (2004) investigate that enhanced industrialization, population and per capita income growth, improved standard of living and modernization are responsible for electricity consumption.

To examine relationship between electricity consumption and economic growth Tang (2008) conducted research and revealed that in Malaysia both causes each other i.e. *GDP* is a possible reason causing energy consumption and *viz*. energy consumption is becoming a reason for *GDP* of Malaysia. Odhiambo (2009) reinvestigated relationship for South Africa and concluded a bidirectional relation between electricity consumption and economic growth in South Africa. Ouédraogo (2010) found a bidirectional relation between electricity consumption and *GDP* in terms of *GDP* per capita both for long- and short-term in Burkina Faso for the time span 1968-2003. Tsani (2010) studied relationship at aggregated and disaggregated level in Greece for time period 1960-2006 and revealed a unidirectional relation from electricity consumption towards economic growth. While at disaggregate level a bidirectional connection exists between both industrialized and residential electricity consumption. Kouakou (2011) conducted study on Cote d'Ivoire using statistical data from 1971 to 2008 and showed a bidirectional relation between electricity consumed per capita and *GDP* growth per capita. Presley and Zoumara (2012) conducted study on Liberia; employment is incorporated as an additional variable. Results revealed a bidirectional relation between energy consumption and economic growth in terms of *GDP*. Belaid and Abderrahmani (2013) examined relationship between electricity consumption, petroleum price and economic development in Algeria from 1971 to 2010. Experimental results revealed a strong bidirectional relation between electricity consumption and *GDP* growth both for long-run and short-run. Solarin and Shahbaz (2013) conducted research to study relationship between *GDP*, urbanization and electricity consumption in Angola from time period 1971 to 2009. Results revealed bidirectional relation between electricity consumption and economic development.

Yoo (2005) conducted research to find relationship in Korea from 1970 to 2002. The results revealed that a unidirectional short-run relation exists from electricity consumption towards *GDP* growth, and a unidirectional long-run nexus from economic growth towards electricity consumption. Mozumder and Marathe (2007) conducted study on Bangladesh, results revealed a one-way relation running from real *GDP* growth towards electricity consumption. Chandran et al. (2010) studied relationship for year 1971-2003 of Malaysia. Results of causality test proved a unidirectional flow from electricity consumption towards economic growth. Gurgul and Lukasz (2012) conducted study in Poland from quarterly 2000 to quarterly 2009. A unidirectional nexus was found from industrial electricity consumption and employment after 2008 crisis and no such relation was found between industrial consumption and *GDP* growth. Akinlo (2009) investigated a causal nexus for Nigeria during 1980-2006. The results show a unidirectional relation from electricity consumption towards *GDP* growth. Ho and Siu (2007) examined and found unidirectional causal relation was found from electricity consumption and economic growth. Ahmad and Islam (2011) made an attempted to determine relationship in Bangladesh using data span from 1971 to 2008. Co-integration results revealed that there exists long-term equilibrium while Granger causal tests suggested unidirectional nexus running from energy consumption per capita to *GDP* per capita. Acaravci and Ozturk (2012) examine the short-run and long-run causality issues between electricity consumption and economic growth in Turkey for 1968-2006 period by using Granger causality models augmented with a lagged error-correction term (*ECT*). The bounds F-test for co-integration test yields evidence of a long-run relationship between employment ratio, electricity consumption per capita and real *GDP* per capita. The overall results from the three error-correction based Granger causality models show that there is an evidence of unidirectional short-run, long-run and strong causalities running from the electricity consumption per capita to real *GDP* per capita. Pempetzoglou (2014) examines the potential linear and non-linear causal relationship between electricity consumption and economic growth in Turkey during the time period 1945-2006. The findings provide evidence for the existence of a unidirectional non-linear causality between income and electricity consumption at the aggregate level. The results also support the presence of a unidirectional linear flow running from economic growth towards residential, commercial and street illumination electricity consumption as well as a unidirectional non-linear flow running from the residential and commercial electricity consumption towards economic growth and from income to electricity consumption for street illumination. Policies should focus on promoting electricity consumption, especially in the residential and commercial sectors to drive economic growth.

Wandji (2013) investigated the relationship for Cameroon. Granger causality tests showed a strong unidirectional nexus from oil consumption towards real *GDP* growth. Abosedra et al. (2009) conducted research using time span of January 1995 to December 2005. Results revealed that there exists a causal relation from electricity consumption towards economic growth. Shengfeng et al. (2012) conducted research to re-investigates relationship between real *GDP* growth and economic development in China. Results proved a unidirectional causal relation from electricity consumption towards economic growth. Cheng et al. (2013) states that previous studies proved that electricity consumption and economic development both corresponds each other and directly affects. By using econometric techniques, analysis was done for annual growth data of China's *GDP* and the electricity generation from 1953 to 2010. Findings reveal that electricity generation causes increase in *GDP* rate but not *viz*. Shahbaz et al. (2011) conducted a study to discover relationship between electricity consumption, *GDP* and employment in Portugal for time period of 1971-2009. Results revealed a short-run one-way causal nexus exists from *GDP* towards electricity consumption. A long-run bidirectional relation exists between the respective variables.

Bose and Shukla (1998) examined how sensitive are sectoral electricity consumption with respect to electricity shortages. Electricity shortages data are likely to capture the electricity reliability factor and its influence on electricity consumption. Results of electricity shortage elasticity show that with 1% increase in electricity shortages the electricity consumption decreases by 0.21% in residential sector 0.30% in commercial sector. Jamil and Ahmad (2010) states that in Pakistan electricity shortfall has been observed since 1980's and up till now handled by load management. An empirical analysis was carried out by him both on aggregate level and sector wise and study revealed that there exists a unidirectional nexus from *GDP* towards electricity consumption. Javid et al. (2012) conducted research to examine long-term relation between *GDP* per capita and electricity consumption for time span of 1971-2008 in Pakistan. The results revealed that there exists a unidirectional relation that is from electricity consumption towards *GDP* growth rate. Zaman et al. (2012) in his study revealed that from 1975 to 2010 there exists a long-run relation between electricity consumption, *GDP*, foreign investment, population growth rate. Short-run causality shows that there is unidirectional causality i.e., from population growth to electricity consumption in Pakistan. Abbas and Choudhury (2013) conducted research to find relationship between electricity consumption and *GDP* growth in Pakistan and India. Causality tests at aggregated and disaggregated levels revealed that for Indian Agricultural Sector, a feedback nexus exists between electricity consumption in agriculture and *GDP*. In Pakistan results suggested causal relation from agricultural *GDP* towards electricity consumption in this sector. Tang and Shahbaz (2013) in his research on Pakistan concluded that from 1972 to 2010 there exist co-integration both at aggregate and sectoral levels. Also electricity consumption is causing an increase in *GDP* growth in manufacturing, and service sector to improve respectively. Alter and Syed (2011) concluded that from 1970 to 2010 electricity was found to be necessity in short-run and eventually become luxury in long-term.

It is apparent from prior investigations of Ho and Siu (2007), Shiu and Lam (2004) and Narayan and Singh (2007) that electricity consumption caused *GDP* however, on other hand it is additionally obvious from prior investigations of Ghosh (2002), Jumbe (2004) and Narayan and Smith (2005) that increase in *GDP* bringing an increase in electricity consumption.

Whereas in case of Pakistan according to Khan and Qayyum (2009) income, electricity prices, temperature, and number of customers appear as important determinants in electricity demand function. Results of study by Shahbaz and Lean (2012), Abbas and Choudhury (2013) claims bidirectional causal relationship between electricity consumption and economic growth. Results by Shahbaz et al. (2012), Javid et al. (2012) and Tang and Shahbaz (2013) claims that energy consumption causes *GDP*. Results by Jamil and Ahmad (2010) claims unidirectional causality running from economic growth and electricity price to electricity consumption.

The results varied for every country they come out to be different for various nations, also it is evident from above discussion that in case of Pakistan the results vary from author to author. Even for a single country, contrasting results was observed with changes in the time period of the data and/or econometric techniques used for the analysis (Payne, 2010).

Electricity shortages an important explanatory variable used by Bose and Shukla (1998) in his study for to examine how sensitive is electricity consumption with respect to electricity shortages in India. It is crucially needed to examine how much sensitive is electricity consumption with respect to its major determinants like *GDP*, number of customers, electricity price and electricity shortages in case of Pakistan.

3. ECONOMETRIC METHODOLOGY

This study is based upon annual information of electricity consumption, *GDP*, electricity customers, electricity price, and electricity shortages coating a period from 1972 to 2012 in Pakistan. In order to avoid seasonal biases, annual datum is used in this study. Two major factors constrained the choice of the starting period, i.e., energy crisis of the 1970s all over the world and the political instability in Pakistan of 1971.

3.1. Model

Theoretically, energy demand is identified with income and prices of energy. This is an essential demand function proposed in numerous economic reading material. Marshallian theory of demand for goods and services is used to infer theoretical models which are utilized for energy demand (Altinay, 2007). The basic model incorporates the real price of energy and real income as explanatory variables (Sterner and Dahl, 1992). Therefore, the theoretical electricity consumption function might be composed as follows (Equation 1):

$$ECO_t = f(GDP_t, ETR_t) \tag{1}$$

Where, ECO_t is electricity consumption, GDP_t is income or economic growth (*GDP*) and ETR_t is the electricity price. Aqeel and Butt (2001), Khan and Qayyum (2009), Jamil and Ahmad (2010), Zaman et al. (2012), Alter and Syed (2011), Shahbaz and Lean (2012), Shahbaz et al. (2012), Javid et al. (2012), Abbas and Choudhury (2013) and many others have already used variables like electricity consumption, economic growth, electricity price in their studies for Pakistan.

Number of electricity customers and electricity shortages have been used as control variables. Electricity shortages an important variable used by Bose and Shukla (1998) in his study to examine sensitivity of electricity consumption with respect to electricity shortages in India. It is needed to examine how much sensitive is electricity consumption with respect to electricity shortages in case of Pakistan. Hence for Pakistan, the new electricity consumption model is given (Equation 2):

$$ECO_t = f(GDP_t, CUS_t, ETR_t, ESH_t) \tag{2}$$

Log linear model have been preferred over the linear model by Khan and Ross (1977). Gujarati (1995) also advocated log transformation who states that hetrokedasticity problem can be minimized by compression of the scale. Studies by Doroodian et al. (1994), Sinha (1997) and Rijal et al. (2000) have performed the Box and Cox (1964) procedure and have shown that the log linear transformation are more effective compared to linear transformation. Log linear specification of the model yield elasticities which according to Varian (1988) helps in managing demand, behavior analysis of demand, forecasting electricity demand and policy analysis.

For the empirical specification of electricity demand model the studies of Khazzoom (1973), Wilder and Willenborg (1975), Halvorsen (1975), Ranganathan (1984), Beenstock et al. (1999), Filippini (1999), Clements and Madlener (1999), Al-Faris (2002), Filippini and Pachauri (2004), Narayan et al. (2007), Ziramba (2008), Dilaver (2008), Khan and Qayyum (2009), Neeland (2009), Arisoy and Ozturk (2014) and many other authors have seized electricity demand as log linear function of its determinants and have used "reduced form model." Following these studies electricity consumption is modeled in log-linear form and the long-run electricity consumption function takes the following form:

$$\ln ECO_t = \alpha_0 + \alpha_1 \ln GDP_t + \alpha_2 \ln CUS + \alpha_3 ETR_t + \alpha_4 \ln ESH_t + \varepsilon_t \tag{3}$$

Here in Equation 3 ln denotes the natural logarithm, lnECO_t is electricity consumption, lnGDP_t is economic growth (*GDP*), lnETR_t is electricity price, and lnESH_t is electricity shortages. The error term ε_t is assumed to be spherically distributed and white noise. The expected signs of for the parameters of *GDP*, number of customers, electricity price and electricity shortages are $\alpha_1 > 0$, $\alpha_2 > 0$, $\alpha_3 < 0$, $\alpha_4 < 0$, respectively.

3.2. Data Collection

Data for electricity consumption, number of customers, electricity shortages, and real electricity price have been arranged from different sources like NTDC. The time series data for real *GDP* is gathered from various issues of Economic Survey of Pakistan. All these variables are expressed in natural logarithm. Economic growth, number of electricity customers variables are expected to have significant positive, while electricity price and electricity shortages are predicted to have negative effect on electricity consumption in Pakistan (Table 1).

3.3. Methods

To overcome the issue of spurious regression, time series econometrics keeps tabs on the time series properties of the economic variables. Before doing any empirical work, examination of time series whether it is stationarity or non-stationarity is important which is closely linked to the testing for unit roots. For each variable we need to determine the order of integration before applying the co-integration technique, for which we used augmented Dickey–Fuller (ADF) test.

Co-integration may give helpful information about the relationship between the non-stationary variables. Co-integration theory endeavors to study interrelationships between long-run movements in economic time series. To check co-integration between electricity consumption and its major determinants in Pakistan Johansen co-integration test has been proposed for this study.

In case of this study there are five variables, lnECO_t, lnGDP_t, lnCUS_t, lnETR_t and lnESH_t, which can all be endogenous, i.e., we have that (using matrix notation for Z_t = [lnECO_t lnGDP_t lnCUS_t lnETR_t lnESH_t]).

$$Z_t = A_1 Z_{t-1} + A_2 Z_{t-2} + \ldots + A_k Z_{t-k} + u_t \tag{4}$$

Which is comparable to the single-equation dynamic model for two variables. Thus, in a vector error correction model (VECM) it can be reformulated as follows (Equation 5):

$$\Delta Z_t = \Gamma_1 \Delta Z_{t-1} + \Gamma_2 \Delta Z_{t-2} + \cdots + \Gamma_{k-1} \Delta Z_{t-k-1} + \Pi Z_{t-1} + u_t \tag{5}$$

Where, $\Gamma_i = (I - A_1 - A_2 - \ldots - A_k)$ $(i = 1, 2\ldots\ldots, k-1)$ and $\Pi = -(I - A_1 - A_2 - \ldots - A_k)$. Here we need to cautiously examine the 5 × 5 Π matrix (The Π matrix is 5 × 5 due to the fact that we have five variables of interest in Z_t = [lnECO_t lnGDP_t lnCUS_t lnETR_t lnESH_t]). The information regarding the long-run relationships is contained in Π matrix. In fact $\Pi = \alpha\beta^{/}$ where α will incorporate the velocity of tuning back to equilibrium coefficients and $\beta^{/}$ will be the long-run matrix of coefficients.

Therefore the $\beta^{/} Z_{t-1}$ term is equivalent to the *ECT*, that in multivariate framework can contains up to (n−1) vectors.

Using annual data taken k = 2, so that we have only two lagged terms, and the model is then the following (Equation 6):

Table 1: Variable name, measurement, expected sign and data source

Variables	Measurement	Expected Sign	Data source
Electricity Consumption (ECO)	GWh		NTDC Power Statistics 37th Edition
Economic Growth (GDP)	Real GDP in PKR	Positive	Economic Survey of Pakistan
Electricity Customers (CUS)	Number of electricity customers	Positive	NTDC Power Statistics 37th Edition
Electricity Price (EIR)	Electricity price in PKRGWh	Negative	NTDC Power Statistics 37th Edition
Electricity Shortages (ESH)	GWh	Negative	NTDC Power Statistics 37th Edition

GWh: Gigawatt-hours, GDP: Gross domestic product, PKRGWh: PKR per Gigawatt hours

$$\begin{pmatrix}\Delta\ln ECO_t\\ \Delta\ln GDP_t\\ \Delta\ln CUS_t\\ \Delta\ln ETR_t\\ \Delta\ln ESH_t\end{pmatrix}=\Gamma_1\begin{pmatrix}\Delta\ln ECO_{t-1}\\ \Delta\ln GDP_{t-1}\\ \Delta\ln CUS_{t-1}\\ \Delta\ln ETR_{t-1}\\ \Delta\ln ESH_{t-1}\end{pmatrix}+\Pi\begin{pmatrix}\Delta\ln ECO_{t-1}\\ \Delta\ln GDP_{t-1}\\ \Delta\ln CUS_{t-1}\\ \Delta\ln ETR_{t-1}\\ \Delta\ln ESH_{t-1}\end{pmatrix}+e_t \tag{6}$$

Or

$$\begin{pmatrix}\Delta\ln ECO_t\\ \Delta\ln GDP_t\\ \Delta\ln CUS_t\\ \Delta\ln ETR_t\\ \Delta\ln ESH_t\end{pmatrix}=\Gamma_1\begin{pmatrix}\Delta\ln ECO_{t-1}\\ \Delta\ln GDP_{t-1}\\ \Delta\ln CUS_{t-1}\\ \Delta\ln ETR_{t-1}\\ \Delta\ln ESH_{t-1}\end{pmatrix}+\begin{pmatrix}\alpha_{11}&\alpha_{12}\\ \alpha_{21}&\alpha_{22}\\ \alpha_{31}&\alpha_{32}\\ \alpha_{41}&\alpha_{42}\\ \alpha_{51}&\alpha_{52}\end{pmatrix}$$

$$\begin{pmatrix}\beta_{11}&\beta_{21}&\beta_{31}&\beta_{41}&\beta_{51}\\ \beta_{12}&\beta_{22}&\beta_{32}&\beta_{42}&\beta_{52}\end{pmatrix}\begin{pmatrix}\ln ECO_{t-1}\\ \ln GDP_{t-1}\\ \ln CUS_{t-1}\\ \ln ETR_{t-1}\\ \ln ESH_{t-1}\end{pmatrix}+e_t \tag{7}$$

To figure out the number of co-integrating vectors Johansen (1991, 1995) method used two statistics: The trace test and the maximum Eigenvalue (λ-max) test. The trace test tests the null hypothesis (H_0) that the number of distinct cointegrating vectors is less than or equal to r against a general alternative. The maximum Eigenvalue (λ-max) test tests (H_0) that the number of cointegrating vectors is r against the alternative of (r + 1) cointegrating vectors.

The presence of co-integration between time series does not imply causation. It is suggested by Granger causality test that there will be at least unidirectional Granger causality if there is a co-integration relationship around the variables. To figure out the causality course between electricity consumption and its determinants, the Granger causality test based on the VECM will be utilized. Following VECM has been estimated to ascertain the causality direction (Equation 8):

$$\begin{bmatrix}\Delta\ln ECO_t\\ \Delta\ln GDP_t\\ \Delta\ln CUS_t\\ \Delta\ln ETR_t\\ \Delta\ln ESH_t\end{bmatrix}=\begin{bmatrix}\alpha_1\\ \alpha_2\\ \alpha_3\\ \alpha_4\\ \alpha_5\end{bmatrix}+\begin{bmatrix}A_{11i}\cdots & A_{12i}\cdots & A_{13i}\cdots & A_{14i}\cdots & A_{15i}\\ A_{21i}\cdots & A_{22i}\cdots & A_{23i}\cdots & A_{24i}\cdots & A_{25i}\\ A_{31i}\cdots & A_{32i}\cdots & A_{33i}\cdots & A_{34i}\cdots & A_{35i}\\ A_{41i}\cdots & A_{42i}\cdots & A_{43i}\cdots & A_{44i}\cdots & A_{45i}\\ A_{51i}\cdots & A_{52i}\cdots & A_{53i}\cdots & A_{54i}\cdots & A_{55i}\end{bmatrix}\times$$

$$\begin{bmatrix}\Delta\ln ECO_{t-i}\\ \Delta\ln GDP_{t-i}\\ \Delta\ln CUS_{t-i}\\ \Delta\ln ETR_{t-i}\\ \Delta\ln ESH_{t-i}\end{bmatrix}+\begin{bmatrix}\alpha\\ \gamma\\ \lambda\\ \varphi\\ \vartheta\end{bmatrix}\times\begin{bmatrix}ECT_{t-1}\end{bmatrix}\begin{bmatrix}\xi_{1t}\\ \xi_{2t}\\ \xi_{3t}\\ \xi_{4t}\\ \xi_{5t}\end{bmatrix} \tag{8}$$

The residuals ξ_{1t}, ξ_{2t}, ξ_{3t}, ξ_{4t} and ξ_{5t} are stationary and have spherical distribution. ECT_{t-1} is the lagged ECT resulting from the co-integration equation. The suitable lag order for the VECM is determined by vector autoregressive (VAR) lag order selection criteria. Eventually, the short-run Granger causality test is carried out by computing F-statistics on the lagged explanatory variables while the t-significance of ECT_{t-1} speaks to the long-run causality relation.

4. EMPIRICAL FINDINGS

This study conducted ADF test for unit root analysis to check stationarity and integration order of series, Johansen co-integration test for testing co-integration and multivariate Granger test for causality analysis. In this section results of all these tests are discussed in detail. The detailed results are shown in Table 2.

The results disclose that at level all the variables selected particularly for this research are non-stationary, however, at first differences they are stationary, therefore we say that over a period of 1972-2012 all variables are first differenced stationary or series are integrated of order I(1).

When series are integrated of the same order, we can proceed to test for the presence of co-integration by using Johansen co-integration technique. Results of unit root test (Table 2) indicate that all series are integrated of same order i.e., all series are I(1). Hence we used VAR model based Johansen (1988, 1991) approach to co-integration as it provides consistent results in multivariate cases.

It is necessary to decide the optimal lag structure and the suitable selection of deterministic segments in the VECM framework to test for co-integration with the Johansen-Juselius co-integration approach (Johansen, 1995). To decide the optimal lag structure the system-wise Akaike's information criterion has been employed, which suggested optimal lag length of 2.

Table 3 illustrates the results of Johansen-Juselius co-integration test. Results by λ_{Trace} and λ_{max} indicates the rejection of null hypothesis of no co-integrating vector and results revealed the presence of single cointegrating vector. Therefore, the results in Table 3 confirm the validity and robustness of the long-run relationship between variables.

Since it is evident that electricity consumption and its determinants are cointegrated, computation of short- and long-run coefficients are needed. Long-run coefficients are presented in Table 4.

The results demonstrate that in the long-run, *GDP*, number of electricity customers, electricity price and electricity shortages are statistically significant. The explanatory variables ln*GDP*, ln*CUS* are decidedly identified to ln*ECO*, while ln*ETR* and ln*ESH* are negatively related to ln*ECO*, i.e. assuming that there is 1% increase in *GDP* it will cause 1.025% increase in electricity consumption, from this it can be deducted that electricity is necessity in Pakistan. If there is 1% increase in number of electricity customers it will cause 1.191% increase in electricity consumption, if there is 1% increase in electricity price and electricity shortages, it will

Table 2: ADF test results on level and first difference

ADF test on the levels and on the first difference (1972-2012)							
Variables	Level			First difference			Decision
	None	Constant	Constant and trend	None	Constant	Constant and trend	
ln*ECO*	2.4891 (1)	1.5045 (0)	−2.7319 (1)	−2.7126* (0)	−4.3905* (0)	−4.5473* (0)	Non-stationary at level but stationary at first difference, i.e. I (1)
ln*GDP*	3.1826 (1)	2.2108 (1)	−0.9526 (1)	−0.9816 (0)	−2.6981 (0)	−3.8951* (0)	Non-stationary at level but stationary at first difference, i.e. I (1)
ln*CUS*	1.4738 (2)	−2.0082 (1)	−1.0073 (1)	−1.3042 (0)	−3.3623* (0)	−5.4732* (0)	Non-stationary at level but stationary at first difference, i.e. I (1)
ln*ETR*	4.6724 (0)	−1.5858 (0)	−2.6165 (1)	−4.0677* (0)	−5.7899* (0)	−5.3755* (0)	Non-stationary at level but stationary at first difference, i.e. I (1)
ln*ESH*	2.9134 (0)	1.2888 (0)	−1.4055 (1)	−3.3544* (0)	−4.3232* (0)	−4.56663* (0)	Non-stationary at level but stationary at first difference, i.e. I (1)

The null hypothesis is that the series is non-stationary, or contains a unit root. * Denote the significant at 5% level. The figure in parenthesis is the optimal lag length. ADF: Augmented Dickey-Fuller

Table 3: Johansen cointegration test results

Hypothesized number of CE(s)	λ-trace	5% CV	P values	λ-max	5% CV	P values
None*	84.79398	69.81889	0.0020	33.81000	33.8768	0.0119
At most 1	45.98399	47.85613	0.0742	23.53857	27.58434	0.1517
At most 2	22.44542	29.79707	0.2744	13.30563	21.13162	0.4245
At most 3	9.139792	15.49471	0.3526	8.377982	14.26460	0.3416
At most 4	0.761810	3.841466	0.3828	0.761810	3.841466	0.3828

* Denotes rejection of the hypothesis it the 5% level. CV: Coefficient of variation

cause 0.156% and 0.249% decrease in electricity consumption respectively which reflects the weak link between the price and the consumption of electricity, which creates problems for demand management. This result implies that the consumption reacts minutely 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. Long-run price elasticity describes electricity as a necessity due to the fact that in present times consumption of electricity is significantly high and one cannot think of developed and comfortable life without electricity. Similarly load management strategies are not very effective in decreasing electricity demand because of electricity being a necessity.

The results indicate that *GDP* has solid positive significant effect on electricity consumption which shows that increase in economic activity may expand electricity consumption. In Pakistan economic growth promotes the development in electricity consumption which recommends that on account of electricity consumption energy development strategy ought be adopted in such a manner that development in this sector invigorates economic development (Aqeel and Butt, 2001).

According to results number of electricity clients has a significant positive effect on electricity consumption. Whereas increase in electricity price has noteworthy negative effect on electricity consumption, as the theory suggests that increase in particular commodity price cause decrease in its demand, same is confirmed by results that although today electricity is one of the necessities but increase in electricity price hampers its consumption. Results also indicate that although electricity shortage has significant negative impact on electricity consumption but coefficient is low.

Table 4: Long-run elasticities

Dependent variable=lnECO_t		
Variables	Long-run elasticities	
	Coefficient	T-statistic
Constant	4.0467	3.7661*
lnGDP_t	1.0256	2.5752*
lnCUS_t	1.1911	4.3700*
lnETR_t	−0.1566	−2.0562**
lnESH_t	−0.2490	−3.9225*

* and ** denote the significant at 1% and 5% level respectively

To inspect the stability of long-run parameters the cumulative sum (CUSUM) and CUSUM of squares (CUSUMSQ) tests are applied. Graphs of both CUSUM and CUSUMSQ statistics are plotted in Figures 3 and 4 individually. The long-run coefficients are stable, as indicated in Figures 3 and 4 that the plotted data points are inside the critical bounds.

The results in the short-run dynamic coefficients interfaced with the long-run relationships obtained from the ECM are given in Table 5.

The results in the short-run revealed that explanatory variables *GDP*, number of electricity customers, electricity prices and electricity shortages are statistically significant. A significant finding of this study is that both the short- and long-run coefficients indicated the positive connections for economic growth, number of electricity customers and showed the negative connections for electricity prices and electricity shortages. This is precisely steady with our former anticipation. In short-run the explanatory variables ln*GDP*, ln*CUS* are positively related to ln*ECO*, while ln*ETR* and ln*ESH* are negatively related to ln*ECO*, i.e., if there is 1% increase

Figure 3: Graph of cumulative sum for long run parameters

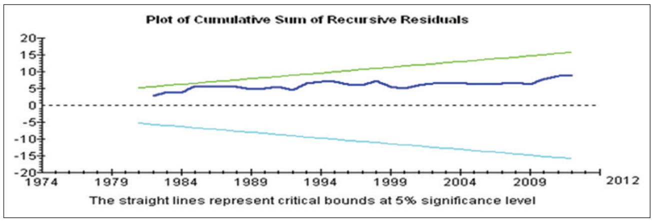


Figure 4: Graph of cumulative sum of squares for long run parameters

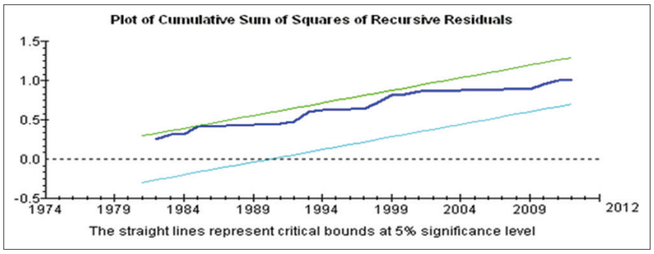


Table 5: Short-run elasticities

Dependent variable = $\Delta\ln ECO_t$		
Variables	**Short-run elasticities**	
	Coefficient	**T-statistic**
Constant	0.3835	3.2684*
$\Delta\ln GDP_t$	0.7336	2.3560**
$\Delta\ln CUS_t$	0.6644	4.3132*
$\Delta\ln ETR_t$	−0.0806	−2.1051**
$\Delta\ln ESH_t$	−0.1281	−4.2161*
ECT_t	−0.5146	−5.9893*
R^2	0.72961	
Adjusted - R^2	0.67892	
F-statistic	14.3915	
D.W	2.5783	

* and ** denote the significant at 1% and 5% level respectively

in *GDP* it will cause 0.733% increase in electricity consumption, if there is 1% increase in number of electricity customers it will cause 0.664% increase in electricity consumption. If there is 1% increase in electricity price it results in 0.080% decrease in electricity consumption and if there is 1% increase in electricity shortages then it will cause 0.128 % decrease in electricity consumption.

The error correction coefficient (ECT_{t-1}) estimated at −0.514, it has right sign and is statistically significant. The established relationship among the variables of interest is confirmed by the significance of coefficient of ECT_{t-1}. Moreover, as implied by the negative sign the divergence in short-run towards long-run is rectified by 51.4% from the past period to the present period, i.e. in the current year approximately 51.4% of disequilibrium converge back to the long-run equilibrium from the previous year's shock.

The presence of co-integration between electricity consumption, economic growth, number of electricity customers, electricity price and electricity shortages infers that there must be no less than one way of Granger causality, yet it does not demonstrate the bearing of causality. In case of Pakistan electricity prices are determined by market mechanism, they are being determined by external factor which is a separate entity National Electric Power Regulatory Authority (NEPRA), which regulates electricity prices all over Pakistan. This shows that electricity prices is an exogenous variable in this model. Therefore, to test the bearing of causality Granger proposes assessing a VECM to test causality course between electricity consumption, *GDP*, number of electricity customers, electricity price and electricity shortages in Pakistan. Table 6 exhibits the short- and long-run Granger causality results. It was specified prior that VECM gives short- and long-run causal relationship amongst electricity consumption, *GDP*, number of electricity customers, electricity price and electricity shortages. The long-run Granger causality is analyzed through the significance of the one period lagged error-rectification term ECT_{t-1}, while the joint significance of the lagged explanatory variables infers the short-run causality.

Starting with the short-run causality, observed outcomes show that electricity consumption is discovered to be statistically significant in electricity customers (Model C). Economic growth is statistically significant in electricity consumption (Model A), number of customers (Model C), electricity price (Model D) and electricity shortages (Model E) equations respectively. Number of electricity customers is statistically significant in electricity consumption (Model A) and electricity shortages (Model E) equation respectively. Electricity price is discovered to be statistically significant in electricity consumption (Model A) equation and statistically significant in number of electricity customers (Model C) equation. This shows that in short-run there is unidirectional causality running from *GDP* to electricity consumption, *GDP* to number of electricity customers, *GDP* to electricity price, *GDP* to electricity shortages, electricity price to electricity consumption, electricity price to number of electricity customers, number of electricity customers to electricity shortages, whereas electricity consumption and number of electricity customers have bidirectional causality in short-run.

Turning to the long-run causality, different indication has been found in comparison with short-run causality. Experiential confirmation indicates that the one period lagged error-correction terms ECT_{t-1} were rejected in electricity consumption, *GDP*, in number of electricity customers. The empirical outcome show that the estimate of ECT_{t-1} i.e., −0.6826 for electricity consumption, −0.1831 for economic growth and −0.1817 for number of electricity customers and 1.2879 for electricity shortages is statistically significant. This infers that a 0.6826% progression in electricity consumption, 0.1831% changes in *GDP* and 0.1817% changes in number of electricity customers are remedied by divergence in short-run towards long-run equilibrium path.

Whereas the estimate of ECT_{t-1} i.e., 0.1251 for electricity price is insignificant which shows that electricity price is not being determined by market and is being affected by some external factor. Also the results of block exogeneity test (Table 7) shows that Model D when tariff is taken as dependent variable is weakly exogenous. In case of Pakistan the external factor which determines the electricity prices is NEPRA, which has full authority awarded by honorable President Islamic Republic

Table 6: Multivariate granger causality

Model	Dependent variable	Multivariate Granger causality analysis: Short-run $\Delta \ln ECO_t$	$\Delta \ln GDP_t$	$\Delta \ln CUS_t$ F-statistics [P values]	$\Delta \ln ETR_t$	$\Delta \ln ESH_t$	Long-run ECT_{t-1} [t-statistics]
A	$\Delta \ln ECO_t$	-	9.6138**	5.8286***	6.2789***	2.0373	−0.6826***
			[0.0007]	[0.0081]	[0.0060]	[0.1507]	[−5.2732]
B	$\Delta \ln GDP_t$	1.0250	-	2.1489	1.5593	0.7970	−0.1831***
		[0.3728]		[0.1369]	[0.2293]	[0.4613]	[−2.9203]
C	$\Delta \ln CUS_t$	7.2903***	3.5743**	-	2.7757*	1.5250	−0.1817**
		[0.0031]	[0.0425]		[0.0808]	[0.2364]	[−2.5634]
D	$\Delta \ln ETR_t$	1.1825	0.9376**	0.8613	-	0.0958	0.1251
		[0.3224]	[0.0160]	[0.4343]		[0.9089]	[0.2230]
E	$\Delta \ln ESH_t$	1.9926	2.6619*	4.2029**	1.5334	-	1.2979***
		[0.1566]	[0.0888]	[0.0262]	[0.2244]		[2.8311]

***, ** and * denote the significant at the 1%, 5%, and 10% levels, respectively

Table 7: Block exogeneity test results

Model	Dependent variable	Block exogeneity test: Excluded variables $\Delta \ln ECO_t$	$\Delta \ln GDP_t$	$\Delta \ln CUS_t$	$\Delta \ln ETR_t$	$\Delta \ln ESH_t$	All Chi-square [P values]
A	$\Delta \ln ECO_t$	-	19.2276***	11.6573***	12.5578***	4.0747	29.9903***
			[0.0001]	[0.0029]	[0.0019]	[0.1304]	[0.0002]
B	$\Delta \ln GDP_t$	2.0500	-	4.2978	3.1187	1.5941	5.5311
		[0.3588]		[0.1166]	[0.2103]	[0.4506]	[0.6996]
C	$\Delta \ln CUS_t$	14.580***	7.148**	-	5.551*	3.050	31.816**
		[0.0007]	[0.0280]		[0.0623]	[0.217]	[0.0001]
D	$\Delta \ln ETR_t$	2.365	1.875	1.722	-	0.191	6.460
		[0.3065]	[0.3916]	[0.4226]		[0.9086]	[0.5958]
E	$\Delta \ln ESH_t$	3.985	5.323*	8.405**	3.166	-	34.185***
		[0.1363]	[0.0698]	[0.0150]	[0.2053]		[0.0000]

***, ** and * denote the significant at the 1%, 5% and 10% levels, respectively

Table 8: Results of multivariate granger causality diagnostics test

Model	Dependent variable	R^2	Adjusted - R^2	F-statistic	Residual diagnostics: $\chi 2$ NORMAL Jarque-Bera	$\chi 2$ SERIAL F-statistic	$\chi 2$ BRELSCH F-statistic	$\chi 2$ ARCH F-statistic
A	$\Delta \ln ECO_t$	0.737	0.626	6.647	1.400 [0.496]	0.210 [0.811]	0.553 [0.879]	0.300 [0.587]
B	$\Delta \ln GDP_t$	0.443	0.215	1.925	0.105 [0.948]	0.673 [0.516]	0.940 [0.539]	0.380 [0.541]
C	$\Delta \ln CUS_t$	0.706	0.582	5.685	1.703 [0.426]	0.190 [0.827]	1.371 [0.244]	0.093 [0.762]
D	$\Delta \ln ETR_t$	0.239	−0.081	0.745	1.149 [0.562]	0.455 [0.639]	1.028 [0.464]	0.082 [0.776]
E	$\Delta \ln ESH_t$	0.603	0.435		0.593 [0.743]	0.706 [0.503]	0.400 [0.963]	2.465 [0.125]

[] indicates P values

of Pakistan to regulate electricity prices under Section 31 of the Regulation of Generation, Transmission and Distribution of Electricity Act (XL of 1997).

Our results are consistent to the previous studies conducted by Zachariadis and Pashourtidou (2007) for Cyprus, Odhiambo (2009a) for South Africa, Tang (2009), Lean and Smyth (2010) and Tang and Tan (2013) for Malaysia, Ouédraogo (2010) for Burkina Faso, Solarin and Shahbaz (2013) for Angola, Alter and Syed (2011), Shahbaz and Feridun (2012), Abbas and Choudhury (2013) for Pakistan and closer to results of study conducted by Zaman et al. (2012).

Residual diagnostic tests like Breusch–Pagan-Godfrey of heteroskedasticity, autoregressive conditional heteroscedastic (ARCH) test of heteroskedasticity, Breusch-Godfrey serial correlation Lagrange multiplier (LM) test and normality test has been performed for all models. Table 8 shows results of these tests for all models.

Results of ARCH test of heteroskedasticity show that the residuals are homoskedastic and here is no ARCH affect in all models, which are desirable. Results of serial correlation LM test indicates that residuals of all models are not serially correlated, which is desirable. Residual normality test indicates that residuals of all the models are normally distributed, which is desirable.

5. CONCLUSION

Through co-integration and causality analysis an endeavor has been made to investigate the electricity consumption function for Pakistan from 1972 to 2012. Unlike the earlier studies on this subject in order to augment the unwavering quality of assessments contribution to the existing literature has been made by including number of electricity customers, electricity price and electricity shortages in the electricity-growth relationship.

The results indicate that electricity consumption and its major determinants are cointegrated in Pakistan. *GDP* and number of electricity customers positively contribute to the electricity consumption, whereas electricity price and electricity shortages influence negatively on electricity consumption in long-run.

The negative effect of electricity price and electricity shortages on electricity consumption implies that increase in price and load management strategies can be used as a tool to control the electricity consumption or it can urge consumers to utilize electricity in an efficient manner. In country like Pakistan where electricity demand is high and also there is installed capacity to meet demand but due to improper price and poor bill recoveries circular debt issue has raise which in turn cause electricity shortages.

Also found that electricity consumption has bidirectional causality with number of electricity customers, whereas there is unidirectional causality running from number of electricity customers to electricity shortages, electricity consumption to number of electricity customers, electricity consumption to electricity shortages and electricity price to electricity consumption.

After realizing importance of electricity which is necessity in Pakistan and economic development dependence on it, especially in a developing nation like Pakistan efforts must be made on immediate basis in electricity generation. To overcome the crisis everybody needs to play a role at every level. Policies must be amended supporting investment in electricity sector. All these needs to be done to sustain and increase economic development and to keep pace with other countries. In order to be a successful country, it needs a powerful and sufficient electricity generation to become a prosperous state.

Furthermore, Government must impose ban on import of less efficient electronic goods and there must be high quality standards for locally manufactured electronic goods (less efficient electronic goods causes unnecessary increase in electricity consumption), as with increase in economic growth income level increases which increases purchasing power.

In the long-run government must go for exploration of alternative environment friendly or renewable energy sources for electricity generation such as solar, wind and hydro etc. Awareness campaigns must be organized in order to inculcate awareness of utilizing electricity properly without wastage.

Additionally Pakistani government should pay attention on investing in research and development programs to design efficient electricity conservation strategies. Furthermore, there is need to enhance energy management expertise to cope with crises in an efficient way.

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