AN EMPIRICAL ANALYSIS OF ENERGY SHORTAGE IN PAKISTAN

*Mubashir Qasim and Koji Kotani**

In this paper, the electricity shortage in Pakistan is addressed through an examination of data over the period 1971-2010 with a time-series analysis. The novelty of the study lies in characterizing energy shortages using both an index comprising the demands for electricity, gas and oil, and information on the public electricity supply. This index allows for a simple empirical approach where energy shortages cannot be directly measured as data. The main findings are as follows: first, end consumers adjust their energy demands to prices only in the long run; second, the underutilization of installed power-generation capacity encourages fossil fuel consumption for private electricity; third, an uninterrupted electricity supply could be attained by regulating private electricity generation; and fourth, the relative demand for electricity increases with an increase in real income and then starts to decrease as income increases beyond the threshold of $1,127. Overall, the results of the study suggest that the price adjustment tactics adopted by the Government of Pakistan are not an effective policy to deal with power shortages in the short run. Rather, the Government should focus on improving the utilization rate of installed power plants and on rechannelling the use of oil and gas for public electricity generation. Otherwise, energy shortages will worsen with economic growth in Pakistan.

JEL Classification: Q57, Q58.

Key words: Energy shortage, energy consumption index, electricity prices, oil prices.

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I. INTRODUCTION

Energy is the mainstay of an economy in the contemporary world. Power shortages may harm the overall welfare of a country in a number of ways, for example, by decreasing the total output of energy-intensive sectors (Kessides, 1993). In recent decades, Pakistan has failed to meet the increasing demand for energy for various reasons, including an overreliance on fossil fuels for power generation, swelling oil prices, climate variation, inadequate alternative energy sources and insufficient technological advancement (Kucukali and Baris, 2010; Chaudhry, 2010; Hasan, Subhani and Osman, 2012). In 2011, the total energy shortfall exceeded 6,000 megawatts (MW) compared with a shortfall of 4,000 MW in 2004 (Amer and Daim, 2011). Extended power outages in urban areas reached 8-10 hours in the course of a day, while there were blackouts in rural areas for more than 20 hours in duration (Khan and el Dessouky, 2009; Hasan, Subhani and Osman, 2012; Lodhi and Malik, 2013; Lodhi, Siddiqui and Habiba, 2013). The literature has shown that energy consumption is directly linked with industrial production, economic expansion and the standard of living in Pakistan. Persistent power shortages may retard the economic growth of the country if the issue remains unsolved (Siddiqui, 2004; Bhutto and Karim, 2007; Khan and Ahmed, 2009; Aqeel and Butt, 2001).

Numerous studies have shown that private electricity generation using backup power generators is an obvious indicator of a power shortage because it is generally more expensive than the electricity bought from public power plants. This relationship has been confirmed by several researchers in developing countries facing electricity shortages (Beenstock, 1991; Beenstock, Goldin and Haitovsky, 1997; Adenikinju, 2005; Steinbuks and Foster, 2010). In the context of Pakistan, there are two principal factors governing private electricity production: first, Pakistan is an energy-deficient country; and second, domestic power production, using small backup generators for private consumption, is not regulated by the Government. Pasha, Ghaus and Malik (1989) found that the energy crisis in Pakistan in the 1980s resulted in enormous investment in backup generators. Today, the availability of sophisticated and affordable backup generators has made private electricity generation a habitual practice for even a middle-income family.

With regard to Pakistan, the existing literature has focused on investigating the dynamics of electricity consumption, while the key supply-side determinants have not been considered in the analyses. For instance, Khan and Ahmed (2009) examined energy demand at the disaggregate level (coal, electricity and gas) using annual time-series data for the period 1972-2007. Their regression model was composed of per capita energy consumption, per capita real income and energy prices. Their study highlighted that the demand for electricity and coal is positively correlated with real income and negatively correlated with price in the short run only. The income and price elasticities of gas are higher than those of coal and electricity. Jamil and Ahmad (2010) studied the relationship between electricity consumption, its prices and real income in Pakistan using annual time-series data for the period 1960-2008 and vector error correction models. Their research showed a unidirectional causality running from economic output to electricity consumption and price for the national, residential and manufacturing levels in the long run, and a bidirectional causality between production level and electricity consumption (and price) in the short run for the manufacturing and agricultural sectors.

Chaudhry (2010) employed panel data from 63 countries during the period 1998-2008 to study the relationship between electricity consumption, real per capita income and electricity prices. Findings of this research suggested that electricity consumption at both the household and national levels increases with real per capita income in Pakistan. An output function analysis showed that an electricity shortage would cut the production of small-scale industries that did not have their own electricity generation capacity, whereas it would increase the cost of production for large firms that own electricity production using expensive inputs. None of these studies, however, provided empirical evidence of the underlying problem, that is, the cause of the electricity shortages.

Only one recent study – by Hasan, Subhani and Osman (2012) – investigated the dynamics of electricity shortages, using power outage data from the Karachi Electric Supply Corporation for Karachi, Pakistan. They employed monthly data from January 2009 to December 2011 using Pearson correlation, vector auto-regressive and Tobit models to explore inefficiencies in the power sector. This study confirmed the existence of a vast power shortfall that is increasing over time, harming economic activity; it highlighted the fact that long power breakdowns cannot reduce the shortfall. The study further underscored the fact that past electricity shortages determine current price levels. However, the approach used in the study cannot be adopted to conduct a study at the national or more aggregate levels due to the absence of power outage data.

There are several works that examine from a microeconomic perspective the energy shortage or power outage problems that have occurred in Pakistan. Sanghvi (1982; 1983), Beenstock (1991), Tishler (1993), and Beenstock, Goldin and Haitovsky (1997) introduced an analytical framework to quantify the cost of electricity interruptions or power outages by focusing on microeconomic behaviours of energy consumers. Using this framework with survey data, Serra and Fierro (1997) estimated the economic costs of electricity outages in Chile through a “willingness to pay” measurement. There are other papers that quantify the costs of electricity interruptions by employing the same types of “willingness to pay” measurements in

Austria and Sweden (Carlsson and Martinsson, 2008; Carlsson, Martinsson and Akay, 2011; Reichl, Schmidthaler and Schneider, 2013).

Another group of works that analyse power shortages is focused more on production functions of firms or the ownership of backup generators. This approach quantifies the cost of power shortages by measuring lost production, lost leisure time and the cost of using backup generators. De Nooij, Koopmans and Bijvoet (2007) and de Nooij, Leishout and Koopmans (2009) identified the total cost of lost production and lost leisure time using regional data in the Netherlands. Wijayatunga and Jayalath (2008) and Szakonyi and Urpelainen (2013) estimated the impact of power outages on economic activities by explicitly introducing the role of backup generators in Bangladesh and India, respectively.

There are few studies that directly examine the causes of power shortages at the national level considering both the demand and supply sides of electricity within a single framework.[1] Although some researchers have made useful policy recommendations using descriptive analysis to curb the energy crisis in Pakistan, the following empirical questions remain:

- How do energy end users behave in response to changes in the supply side and other socioeconomic factors?
- What is the cause of the power shortages?
- What policy would be effective in solving the energy shortage problem?

Since the existing literature on energy focuses more on energy demand, income and price levels, a new aspect of analysis is addressed in this paper – that is, the supply side of electricity in Pakistan – together with the key variables of price and income. More specifically, the authors have sought to answer the above-mentioned questions by analysing the relative demand for electricity, oil and gas with the key variables of the supply side.

The analysis clarifies the determinants of electricity shortages in Pakistan at the aggregate and sectoral levels (for the household, industrial and agricultural sectors). As a proxy for electricity deficiency, a unique energy consumption index (ECI) was developed and employed. ECI reflects the demand for fossil fuels compared with that of electricity. The index is obtained by dividing the sum of oil and gas consumption by electricity consumption. In this calculation, various energy consumption measurements are converted into a single unit (that is, tons of oil

[1] A straightforward assessment of power shortages is not possible due to the unavailability or unobservability of the relevant power outage data at the national level.

equivalent, or TOE). Under an ideal situation of adequate power supply, ECI should follow a steady pattern of growth over time. In a situation of acute power shortage, when oil and gas are used as a substitute for electricity, ECI fluctuates in both the short run and the long run in the context of Pakistan. Under these assumptions, ECI is a reliable indicator for capturing electricity shortages.[2]

In the study, an Engle and Granger two-step approach and an error correction model were employed to assess the factors responsible for electricity shortages in Pakistan. Using annual data on electricity, gas and oil consumption, electricity and oil prices, real GDP per capita, the utilization of installed capacity (percentage) for electricity production, and electricity production from thermal (fossil fuels and coal) and non-thermal (hydroelectric and nuclear) sources, the following main findings emerged from the present study. First, end consumers adjust their energy demands to prices only in the long run. Second, the underutilization of the installed power-generation capacity encourages fossil fuel consumption for private electricity. Third, an uninterrupted electricity supply could be attained by regulating private electricity generation. Fourth, the relative demand for electricity increases and then decreases with real income in relation to gas and oil. Overall, the findings imply that the price adjustment tactics adopted by the Government are not an effective policy to deal with power shortages in the short run. Rather, the Government should focus on improving the utilization rate of installed power plants and rechannelling the use of oil and gas for public energy generation. Otherwise, energy shortages will worsen with economic growth in Pakistan.

The rest of this paper is structured as follows. In section II, the supply and the demand of energy in Pakistan are described, along with the country's electricity shortages. There is a brief overview of the electricity, oil and gas sectors of Pakistan. The model, methodology and data are discussed in section III. The empirical results and their interpretation are discussed in section IV, while the conclusion, policy implications and recommendations are presented in the final section.

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[2] The energy consumption index (ECI) fluctuates when electricity shortages and blackouts occur in Pakistan because people use self-generators using oil and gas to back up the supply of electricity. When there is no blackout or no electricity shortage, this means that power plants are providing sufficient electricity. The use of oil and gas when there is no blackout or shortage should be relatively smooth so that ECI must be smooth as well. Therefore, a fluctuation of the energy consumption index is considered to be attributed to the heavy use of backup generators when electricity shortages and blackouts occur in Pakistan.

II. OVERVIEW OF THE ENERGY SECTOR IN PAKISTAN

The shortage of energy and its related problems have continued to restrict Pakistan's economic growth severely due to the country's underdeveloped, inefficient and poorly managed infrastructure.[3] The Government of Pakistan reportedly has not made serious efforts to expand electricity generation capacity to support the country's rapid economic growth during the past decade (Khan and Ahmed, 2009). Consequently, when power demand is greater than the supply, the Government adopts load management through load-shedding and price-increasing tactics. As an immediate attempt to remedy the national power crisis, the Government of Pakistan installed several rental power plants (RPPs) with a generation capacity of about 1,156.1 MW in 2008 and 2009 (Transparency International – Pakistan, 2010).[4] The thermal power expansion of RPPs was criticized by many researchers from the beginning of the project. The Asian Development Bank (2010) claimed that the programme would not be sufficient to eradicate load-shedding; rather, it would exert upward pressure in power production costs. Under RPP scenarios, the end user bears an 80 per cent increase in the tariff. Reports published by the National Electric Power Regulatory Authority show that per unit production costs (of particular RPPs) have exceeded 40 Pakistan rupees (PR) (US$ 1 = currently about 99 PRs), whereas the average selling price per unit is PR 7 (Pakistan, National Electric Power Regulatory Authority, 2004; 2013).

[3] Power theft, bribes and corruption are common in the energy sector in Pakistan, and many utilities continue to receive subsidies. See M.A. Khan and U. Ahmed, "Energy demand in Pakistan: a disaggregate analysis", MPRA Paper, No. 15056 (Munich, University Library of Munich, 2009).

[4] The Government of Pakistan approved the acquisition of 2,700 MW of rental power plants (RPPs) as an immediate measure to narrow the electricity supply-demand gap. However, by December 2009, no RPP had come on stream. Different stages of the RPP programme were approved on the basis of procurement through international competitive bidding. A total of three tenders were floated by the Private Power and Infrastructure Board and six by the Pakistan Electric Power Company to implement the programme. As a result, 14 RPPs were built. In addition, five unsolicited RPPs were approved by the Economic Coordination Committee of Pakistan. There are currently 19 RPPs, with a total capacity of 2,734 MW at various stages of power processing (ADB, 2010). According to most sources, by the end of 2011, only 1 of the 19 RPPs had come on stream, adding to the national grid only 62 MW of electricity against the target of 2,700 MW. On the basis of the figures presented to the Supreme Court of Pakistan, the RPPs contributed on average 118 MW between March 2011 and February 2012, which is less than 1 per cent of the total installed capacity without RPPs. According to Pakistan Water and Power Development Authority statistics, the current energy available from RPPs is 250 MW with 285 MW installed capacity. See Supreme Court of Pakistan, Human rights case Nos. 7734-G/2009 and 1003-G/2010, Islamabad, 2010. Available from www.supremecourt.gov.pk/web/user_files/File/HRC7734-G_1003-GOF2009[AllegedCorruptionInRentalPowerPlants].pdf.; and S. Ahmad, "Myth and reality of rental power plants", *Pakistan Observer,* 1 December 2010.

Despite a hefty increase in electricity prices after 2008, there still exists a significant gap between power generation costs and actual recovery. The Government of Pakistan therefore has to subsidize PR 30 per unit (for some RPPs) to keep the price stable (ADB, 2010).[5] In 2012, only three years after the RPP programme's implementation, it turned out to be a multimillion dollar corruption scam.[6] In 2010, primary energy availability per capita dropped significantly, by 5.26 per cent, as shown in table 1. There has been no major recovery since 2011/12. On the consumption side, all of the types of energy consumption decreased in 2008/09 except gas consumption, as shown in figure 1. In the period 2011/12, oil consumption remained at the same level, whereas gas consumption slightly decreased and electricity consumption slightly increased. These figures suggest that

Table 1. Primary energy supply and per capita availability

Year	Energy supply		Per capita	
	Million (TOE)	Change (%)	Availability (TOE)	Change (%)
2000	43.19	3.51	0.32	1.28
2001	44.40	2.82	0.32	0.36
2002	45.07	1.50	0.32	-1.25
2003	47.06	4.41	0.32	2.86
2004	50.85	8.06	0.34	5.25
2005	55.58	9.26	0.36	6.45
2006	58.06	4.18	0.37	2.48
2007	60.62	4.33	0.38	2.61
2008	62.92	3.78	0.39	2.86
2009	62.55	-0.58	0.38	-2.27
2010	63.09	0.86	0.36	-5.26
2011	64.52	2.3	0.36	0.00
2012	64.73	0.32	–	–

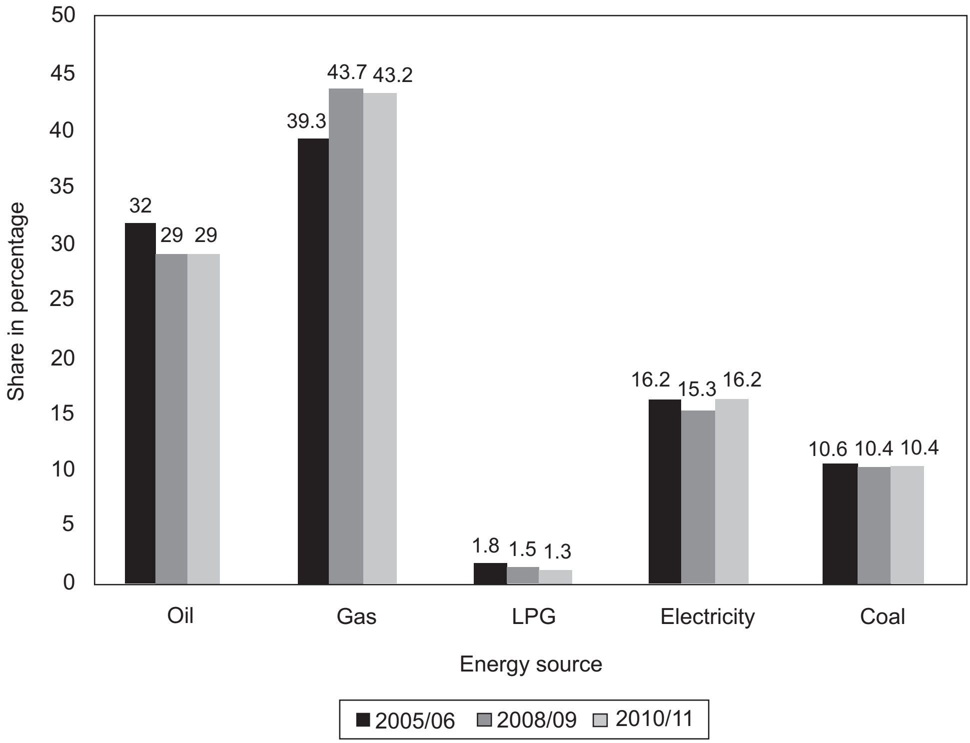
Source: Pakistan, Ministry of Finance, *Pakistan Economic Survey 2012-13* (Islamabad, 2013).

Note: TOE – tons of oil equivalent.

5 The authors initially tried to incorporate the gap in their analysis. This, however, was not possible due to the unavailability of the corresponding data.

6 See Asian Development Bank, *Islamic Republic of Pakistan: Rental Power Review* (Manila, 2010); Mir Shakil-ur-Rahman, ed.,"Summary of SC judgment in rental power plants case", *News International*, 31 March 2012. Available from www.thenews.com.pk/Todays-News-6-100407-Summary-of-SC-judgment-in-Rental-Power-Plants-case; and Pakistan, Ministry of Finance, *Economic Survey 2009-10* (Islamabad, 2010).

Figure 1. Share of energy consumption by source in Pakistan



Source: M. Shoaib, "Energy", in *Pakistan Economic Survey 2012-13* (Islamabad, Pakistan, Ministry of Finance, 2013, p. 187). Available from http://finance.gov.pk/survey/chapters_13/14-Energy.pdf.

Note: LPG – liquefied petroleum gas.

a large share of energy consumption is from oil and gas, which are used to generate electricity with back-up generators.

Why is there an electricity shortage in Pakistan?

The inefficiencies, strengths and challenges of the power sector in Pakistan have been studied by several scholars, although there are few empirical works that characterize the issue. Many scholars have noted that the power production, management and consumption sides are responsible for the current electricity shortages. In Pakistan, production and distribution inefficiencies include more than 20 per cent transmission and distribution losses, an overreliance on thermal power production and the underutilization of installed capacity for power production

(Pakistan, Ministry of Water and Power, 2013). However, the impact of key supply-side variables on energy shortages has been quantified in only a few studies.

Yazdanie and Rutherford (2010) criticized the central structure of the power generation sector. In Pakistan, 66 per cent of the total electricity produced comes from expensive thermal sources,which use 42.8 per cent oil and 28.1 per cent gas of the gross domestic consumption. On the other hand, of the total energy produced in the United States of America, 50 per cent is from coal, 25 per cent from natural gas and the remaining 25 per cent from mixed source (Younos, Hill and Poole, 2009). Scholars have proposed different solutions to overcome the electricity shortage. For instance, Yazdanie and Rutherford (2010) advocated the expansion of renewable power generation capacity. Jamil and Ahmad (2010) emphasized the development of hydroelectric power production capacity. However, Amer and Daim (2011) concluded that there was no single ideal solution that would meet the national energy demand. Pakistan needs a combination of suitable alternative technologies to ensure countrywide energy security.

Government strategies to tackle the electricity shortfall by introducing breakdowns (load-shedding) and increasing electricity prices have been criticized by many scholars because these power cuts not only exacerbate power availability but also play a vital role in determining future electricity prices for both domestic and industrial users (Kessides, 2013). For instance, in 2008, when Pakistan was confronting its worst power shortfall, the Government announced an increase of 62 per cent and 71 per cent in electricity prices for domestic and industrial users, respectively (Hasan, Subhani and Osman, 2012). Meanwhile, the Karachi Electricity Supply Company (KESC) was unwilling to produce electricity from furnace oil due to an increase in the price of oil.[7] In the following years, both power shortfalls and electricity demand stretched a great deal. By the end of 2010, daily electricity demand in Pakistan surpassed 20,000 MW, with an average shortfall of 2,000-4,000 MW per day (Mills, 2012; Zeshan, 2013; Pakistan, Ministry of Water and Power, 2013). Consequently, a considerable number of small- and medium-scale production units shut down due to high energy costs and frequent power shortfalls.

The most prominent feature of energy consumption in Pakistan is that the household sector is the largest consumer of electricity. This sector alone represents more than 46.5 per cent of the country's total electricity consumption, while the industrial sector consumes only 27.5 per cent of the total energy consumed (Pakistan, Ministry of Finance, 2013). In contrast, in developed countries, 15 to 20 per cent of

[7] See, for example, M.W. Bhatti, "KESC fears backlash over hike in furnace oil prices", *News International*, 17 August 2012; and A. Ahmadani, "KESC decides to convert two power plants from oil to coal", *Nation,* 11 September 2013.

total energy is consumed by households (Dzioubinski and Chipman, 1999). Dzioubinski and Chipman (1999) indicated that per capita household energy consumption in North America was much higher in the early 1970s, and it eventually decreased over time. In contrast, energy consumption is moving in the opposite direction in Pakistan, where the usage of energy-efficient electronic appliances is not common.

Electricity sector of Pakistan

The main electricity producers in Pakistan are the Water and Power Development Authority (WAPDA), KESC and the Pakistan Atomic Energy Commission. WAPDA supplies electricity for all of Pakistan with the exception of Karachi, while KESC covers the city of Karachi and its surrounding areas. WAPDA was bifurcated into two separate entities in October 2007, that is, WAPDA and the Pakistan Electric Power Company (PEPCO). WAPDA is responsible for water and hydropower development, whereas PEPCO manages the affairs of 14 different public limited companies in the areas of thermal power generation, transmission, distribution and billing.

Competition in the power generation sectors was introduced in the 1990s, and since then there have been 27 independent power producers contributing significantly to the national energy supply. Pakistan follows the single-buyer model of electricity supply, whereby PEPCO produces thermal power as well as buys electricity from several producers, including independent power producers and the Pakistan Atomic Energy Commission. The majority of independent power producers generate thermal power from natural gas and petroleum products. The independent power producers buy inputs from national oil and gas companies, and frequent disruptions in cash flow cause an unstable electricity supply.

In 1947, at the time of independence, Pakistan inherited 60 MW power generation capacity, which could cater to the needs of the whole population. However, with the acquisition of KESC in 1952 and the establishment of WAPDA in 1958, Pakistan's power sectors flourished rapidly. Despite the fast growth of the energy sector, energy demand has been outpacing aggregate supply due to rapid industrialization, urbanization, population growth and so forth. Electricity supply has lagged behind demand since the early 1980s. The power sector of Pakistan has been unable to maintain the required capacity due to poor governance, institutional weakness, unsuitable tariff structures and poor load management tactics to manage power shortfalls. Today, only 65 per cent of the total population receives its electricity from the main grid, which is an unreliable and highly disrupted supply of electricity.

Oil and gas sector of Pakistan

The Government of Pakistan holds a significant stake in the oil and gas sector as an owner, manager, policymaker and regulator. Oil and gas are key components of Pakistan's energy, meeting over 78 per cent of the country's energy needs. While confronting global oil price shocks, Pakistan's oil-related policies have been focused on minimizing heavy dependence on oil imports. Despite these efforts, the country experienced massive oil supply disruptions on several occasions in the past, including the Iranian boycott from 1951 to 1953, the Suez crisis in 1956, the so-called six-day war in 1967, the Arab-Israeli war in 1973, the Iranian revolution in 1979, the Iran-Iraq war in 1980, the Persian Gulf crisis in 1991 and the global financial crisis that started in 2008.

With its well-developed infrastructure, Pakistan is among the major consumers of natural gas in the region. It has sophisticated natural gas transportation, distribution and utilization systems, with a 9,480 km transmission and 104,499 km distribution network. There are two semi-State-owned gas transmission and distribution companies, namely Sui Northern Gas Pipelines Limited and Sui Southern Gas Company Limited. With more than 3,000 stations supplying compressed natural gas, Pakistan is the world's largest consumer of compressed natural gas (Shoaib, 2013; Gillani and others, 2011). Pakistan does not import or export electricity or gas. Oil is the only traded form of energy. However, two significant regional gas pipeline projects, namely the Islamic Republic of Iran-Pakistan gas pipeline project and the Turkmenistan-Afghanistan-Pakistan-India gas pipeline, are being planned.

III. METHODOLOGY

In the present study, energy shortages are examined using a unique index – ECI_t– as a dependent variable, while energy prices, real income and other supply-side factors are used as explanatory variables. Equation (1) is a mathematical representation of ECI_t for the national, industrial and household levels.[8]

$$ECI_t = \frac{Oil\ consumption_t + Gas\ consumption_t}{Electricity\ consumption_t} \qquad (1)$$

[8] Gas consumption of the agricultural sector is a null value. This is discussed in section IV of the present paper.

To calculate ECI_t, all of the types of energy measurements are converted into a single unit (that is, TOE). It is plausible to assume that constant movements or the smooth growth of the index without many fluctuations over time reflects the ideal situation of no power shortage because this implies that the consumption of all of the types of energy follows steady patterns. For instance, if steady electricity consumption generated by thermal plants with inputs of oil and gas is made over time, ECI_t will be mostly constant or at least smooth. Put more simply, the constant consumption of oil, gas and electricity will keep the index constant.

However, the index can go up or down depending on how the replacement of traditional energy sources with alternative energy sources, such as renewable energy or hydroelectricity generation with backup generators, is made over time. For instance, when hydroelectricity generation is replaced by electricity from backup generators, the index will move up. On the other hand, when hydroelectric energy contributes more to electricity generation and reduces the reliance on backup generators, the index will go down. Thus, a fluctuation in the index is considered to be the indicator of electricity substitution with oil and gas. In the context of Pakistan, people use backup generators fuelled by oil and gas for private electricity, and thus, increases in the index and in the occurrence of blackouts are indicators of an energy shortage. Therefore, by using ECI_t as a dependent variable, it is possible to analyse which factor significantly affects energy or electricity shortages.

In summary, when ECI_t can move up and down depending on replacements of electricity with backup generators using oil and gas, this index can be considered a function of aggregate, as well as sector-wise electricity prices (EP_t), oil prices (OP_t), real gross domestic product per capita (GDP_t), the electricity production ratio from thermal and non-thermal resources ($TNTPR_t$) and the capacity utilized for power production (CU_t). Using these specifications, the following cointegrating equation was used in this study:

$$ECI_t = \beta_0 + \beta_1 EP_t + \beta_2 OP_t + \beta_3 GDP_t + \beta_4 GDP_t^2 + \beta_5 TNTPR_t + \beta_6 CU_t + e_t \quad (2)$$

Where $TNTPR_t$ and CU_t are obtained from the following equations:

$$TNTPR_t = \frac{Thermal\ electricity\ production_t}{Hydroelectric\ production_t + Nuclear\ production_t} \quad (3)$$

$$CU_t = \frac{Actual\ production_t}{Total\ installed\ capacity_t} \times 100 \quad (4)$$

The specification follows previous literature in the sense that the consumption of oil and gas with backup generators is dependent on the various prices of oil, gas and electricity, and on GDP. Accordingly, it can be assumed that ECI_t is also dependent on the same factors. However, there are some unique features in the empirical framework of the present study in the sense that the supply-side variables of $TNTPR_t$ and CU_t are included. This inclusion is made because these variables are controlled by KESC, WAPDA and PEPCO in relation to political factors and to the financial situation of each entity, as described previously in this paper.

Based on economic theory, $TNTPR_t$ and CU_t cannot be included together with energy demand in the regression analysis. However, the supply side of the energy sector in Pakistan has not been functioning according to economic theory. More specifically, the $TNTPR_t$ and CU_t variables are mostly controlled by the public companies, and they are considered exogenous variables, which are usually determined by uncontrollable factors, such as government budgets, rather than by market forces. Therefore, the independent variables can be taken as control variables.

In other words, a change in the consumption of oil and gas through backup generators does not affect the variables of $TNTPR_t$ and CU_t. This can be supported by the fact that backup generators are used only when an electricity shortage occurs, as the electricity generated by backup generators is more costly for users than the grid electricity distributed from power plants (Pasha, Ghaus and Malik, 1989; Kessides, 2013; Lodhi and Malik, 2013). The definitions of the variables and the corresponding units of measurement used in the analysis are summarized in table 2.

Based on economic theory, holding other factors constant, an increase in OP_t, GDP_t, and CU_t should have a negative association with ECI_t. Each of these factors should reduce the use of, or reliance on, backup generators for private electricity. An increase in OP_t should reduce oil and gas consumption and lead to a decrease in ECI_t. An increase in GDP_t should decrease ECI_t because it would reduce the reliance on backup generators. However, in the field of environmental economics, certain non-linear effects, called the “Kuznets curve”, are common, indicating that energy use relies more on oil and gas than on other energy sources in the initial stage of economic growth. However, as the economy grows, energy use moves to cleaner energy sources. Following this argument, a quadratic term of GDP_t is included. With respect to CU_t, it is one indicator of how the installed capacity of public electricity supplies is utilized, and its increase should reduce the use of backup generators and ECI_t accordingly. EP_t is hypothesized to be positively associated with ECI_t because its increase should reduce electricity use and ECI_t would therefore increase with a decrease in its denominator of electricity consumption.

Table 2. Definitions and descriptions of each variable in the regression analysis

Variable name	Description	Unit of measurement
ECI	Energy consumption index. This is an index obtained from the sum of oil consumption and gas consumption divided by electricity consumption. A decline in the value of ECI over time represents a higher usage of electricity compared with the aggregate consumption of oil and natural gas; an increase in the value of the index shows a higher consumption of fossils fuels. A frequent fluctuation indicates an unstable electricity supply and frequent substitution among fossils fuels and electricity.	Tons of oil equivalent
EP	Electricity price	Pakistani rupees per kWh
OP	Oil price	Pakistani rupees per litre
GDP	GDP per capita	United States dollars per person
TNTPR	Thermal and non-thermal production ratio is another index that represents the amount of electricity produced from thermal resources (oil or gas or both) divided by the sum of the electricity produced from hydroelectric and nuclear resources. At steady nuclear energy production, major changes in the value of this index occur as a result of the changes in electricity production from thermal and hydroelectric resources.	GWh
CU	Percentage of the total installed capacity utilized to produce electricity.	Percentage

The coefficient $TNTPR_t$ should provide important implications or a precise interpretation in the context of Pakistan's energy demand. In fact, it is known that the installed capacity to produce electricity from hydroelectric and nuclear sources is stable in both the short run and medium run. However, thermal energy production changes a great deal even over time due to the load-shedding strategies or price-increasing tactics of energy suppliers in Pakistan. Therefore, a fluctuation in $TNTPR_t$ is driven mainly by changes in thermal energy production.

When the coefficient $TNTPR_t$ is inversely correlated with ECI_t, it implies that public thermal electricity production contributes to the reduction of oil and gas consumption through backup generators for private electricity. If it is positively associated with ECI_t, public thermal electricity generation induces a greater consumption of oil and gas than of electricity consumption using the same energy measurement unit (that is, TOE). This means that the existence of public thermal plants for electricity generation in Pakistan cannot be justified from an energy efficiency point of view, which should be an interesting policy question.[9]

The analysis followed the Engle and Granger two-step procedure (Engle and Granger, 1987). In cointegration tests, all variables should be non-stationary or follow a random walk process for the cointegration regression to be meaningful. To identify the order of integration, the stationarity of the variables was pretested with an augmented Dickey-Fuller test with Schwarz information criterion, and the results were double-checked with Akaike information criterion (Dickey and Fuller, 1981). In order to verify the results, the Phillips-Perron unit root test was also employed. Trend and intercept terms were used in these tests to control drift or trend in the data. From the unit root results, if non-stationary time-series data are cointegrated at the same level, it is possible to formulate an error correction model.

The error correction model provides estimates that can help to explain the short-run relationship among the variables. The existence of a cointegration relationship among the variables can be tested by the unit root test of the residual term represented by the following equation:

$$\Delta\hat{e}_t = \alpha\,\hat{e}_{t-1} + \sum_{i=0}^{n} \delta_i\,\Delta\hat{e}_{t-i} + u_t \tag{5}$$

where Δ is the difference operator, $\hat{e}_t$ is the residual from equation (5), $n \geq 0$ is the number of lags which make up the residual of the equation, and α and δ are the parameters to be estimated. The failure to reject the hypothesis, that $\hat{\alpha} = 0$, is evidence that the error term is not cointegrated. In such a case, results of simple ordinary least squares (OLS) to estimate equation (1) do not lead to spurious regression and the OLS parameters are consistent.

[9] The price of gas was not included as an explanatory variable in the model mainly due to the fact that gas prices and oil prices move together in Pakistan. In other words, these types of fuel are perfect substitutes for each other and their prices always move in the same direction. The other reason for not including the price of gas as a covariate was the unavailability of data for the study period.

In the cointegration model, the long-run relationships are summarized and interpreted by the following parameters:

$$\frac{\partial ECI_t}{\partial EP_t} = \beta_1, \frac{\partial ECI_t}{\partial OP_t} = \beta_2, \frac{\partial ECI_t}{\partial GDP_t} = \beta_3 + \beta_4 GDP_t, \frac{\partial ECI_t}{\partial TNTPR_t} = \beta_5, \frac{\partial ECI_t}{\partial CU_t} = \beta_6$$

It should be noted that β_1 and β_2 capture the effect of the price of electricity and the price of oil on the dependent variable. The first order partial derivative of equation (1) with respect to GDP_t will help in identifying a possible non-linear effect as well as the associated turning level of real income for ECI_t if it exists. β_5 and β_6 show the relative effect of thermal and non-thermal electricity generation and the percentage of capacity utilized for electricity generation, respectively.

Finally, the associated error correction model of the cointegration relationship can be estimated by

$$\Delta ECI_t = \alpha_0 + \alpha_1 \Delta EP_t + \alpha_2 \Delta OP_t + \alpha_3 GDP_t + \alpha_4 GPD_t^2 + \alpha_5 \Delta TNTPR_t + \alpha_6 \Delta CU_t + \alpha_7 \hat{e}_{t-1} + \varepsilon_t \quad (6)$$

A first difference of each variable in equation (6) makes I(1) integrated variables stationary. The relationship among stationary variables can be estimated to establish short-run effects among variables, which is one of the main objectives of an error correction model. Therefore, the coefficients of equation (6) are the estimates of the short-run effects of each corresponding independent variable. In addition, the coefficient of error-correction terms, α, is said to be the speed of adjustment for any shock leading to a deviation from the equilibrium in the long run. It is intriguing to note that the sign and significance level of error-correction terms are evidence of long-run equilibrium relationships among the variables in equation (6).

The aforementioned method was chosen because it is one of the simplest methods to identify the association between ECI_t and the other independent variables. To justify the use of this method, it is argued that a fluctuation in ECI_t is driven mainly by a change in oil and gas consumption through backup generators for private electricity, considering the unique contexts of Pakistan's energy consumption. That is, the use of backup generators is affected by independent variables of the regressions, but ECI_t does not directly affect the independent variable. Therefore, a time-series analysis of error correction and cointegration is employed to clarify the short-run and long-run linkage between ECI_t and the other independent variables in a simple way.

Data

Data corresponding to annual observations from 1971 to 2010 were used. The data were gathered from several sources: electricity consumption (measured in GWh) at the aggregate level and by key sectors, namely industrial, household and agricultural levels, as well as the average prices for each category (in PR/kWh), were taken from *Electricity Marketing Data* (WAPDA, 2011). There are different electricity prices in different sectors due to the different levels of subsidization administered by the Government of Pakistan. The data on oil consumption (in tons), gas consumption (in millions of cubic feet), oil prices (in PR/litre) and electric power supply-side series – electricity production from different sources (such as hydroelectric, thermal and nuclear), total electricity production and actual installed capacity – were obtained from the Ministry of Petroleum and Natural Resources and from the Hydrocarbon Development Institute of Pakistan.[10] Finally, real GDP per capita data for the national and sectoral levels were collected from the World Bank.[11]

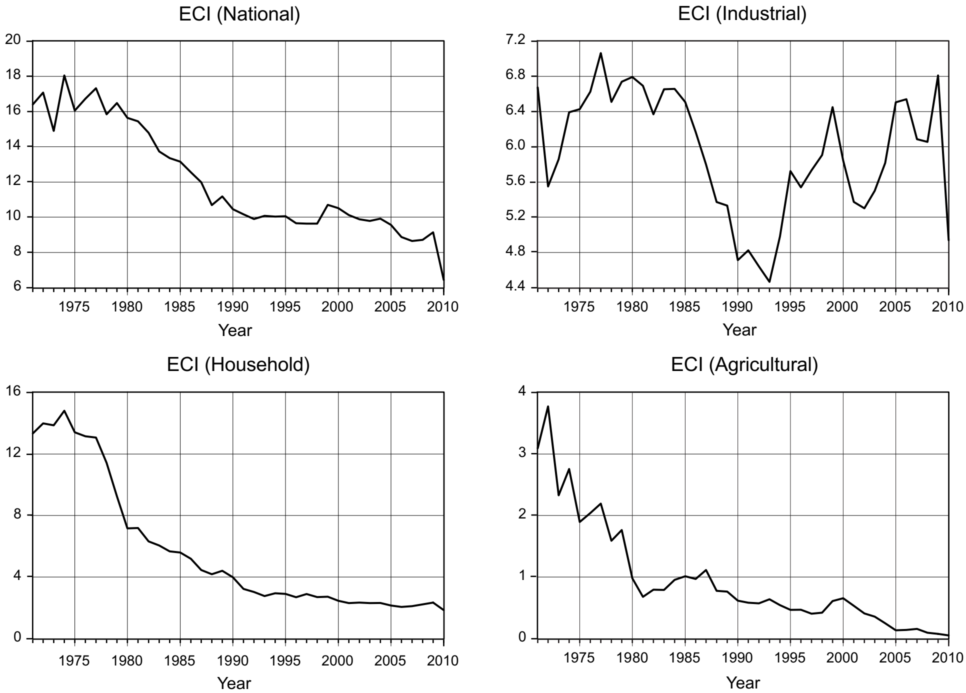
IV. RESULTS AND DISCUSSION

In this section, the long-run and short-run dynamics of electricity fluctuations are provided along with the corresponding estimation results for sample data of Pakistan for the period 1971-2010. In figure 2, which is composed of four subfigures, time-series plots of ECI_t are depicted. Each subfigure corresponds to the national, industrial, household or agricultural sector. As shown in this figure, there is a general tendency for ECI_t to decline over time except in the industrial sector. At the same time, there is high volatility of ECI_t in the energy-intensive sectors, that is, the industrial and agricultural sectors. Especially in the industrial sector, ECI_t fluctuates and does not necessarily decline over time. This implies that oil and gas have been heavily used for backup generators by this sector in response to electricity shortages. Oil and gas consumption for backup generators in the household, agricultural and national sectors appears to have been declining over time based on these data of ECI_t. However, to characterize what has driven the reduction in ECI_t, the effects of several explanatory variables (prices, income and supply side) will be reported.

10 These figures are published in the *Pakistan Economic Surveys* by the Ministry of Finance.

11 See World Bank, World Development Indicators. Available from http://data.worldbank.org/country/pakistan.

Figure 2. Aggregate and sector plots of ECI_t for the period 1971-2010

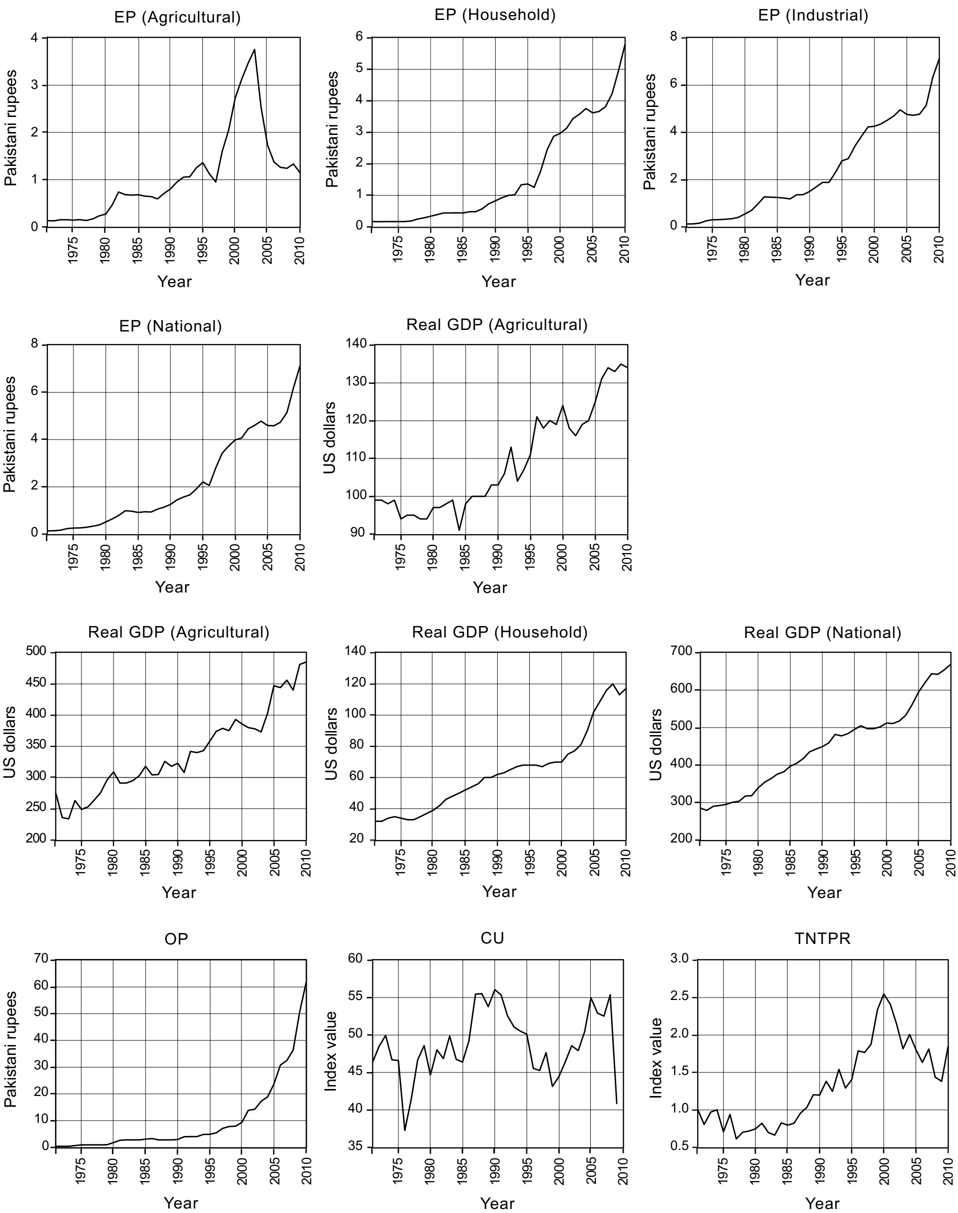


Note: ECI – energy consumption index.

In figure 3, the trends of the time-series data used for this study as explanatory variables are shown. As can be seen, the variables of EP_t, OP_t and GDP_t exhibit the same qualitative feature of time-series plots irrespective of the sector, that is, an upward time trend. On the other hand, it should be noted that the important supply-side variables of CU_t and $TNTPR_t$ exhibit some degree of fluctuation over time. This exemplifies certain problems that Pakistan has faced in electricity generation up to the present; that is, capacity utilization and thermal power generation have not been stable in Pakistan, and this phenomenon signifies energy shortages.

Before conducting further analysis, the order of stationarity is examined. To obtain the exact level of integration, augmented Dickey-Fuller and Phillips-Perron unit root tests were employed. The results of both tests are shown in table 3. The results imply that all of the variables are integrated in order one I(1) and they are consistent with the requirement for the rest of the time-series analysis. This means that individual variables are stationary at their first differences. Hence, cointegration models are estimated with level variables and error correction models with first differences data.

Figure 3. Trends of the relevant variables for the period 1971-2010



Note: CU – capacity utilized; EP – electricity price; OP – oil price; TNTPR – thermal and non-thermal production ratio.

Table 3. Results of unit root tests

Sector and variable	Augmented Dickey-Fuller		Phillips-Perron		Order of integration
	Level	First difference	Level	First difference	
National					
ECI	-0.61	-11.27***	-0.13	-11.05***	I(1)
GDP	0.72	-4.59***	1.28	-4.59***	I(1)
EP	-0.4	-3.23*	0.40	-3.27*	I(1)
Industrial					
ECI	-2.31	-6.09***	-2.32	-6.08***	I(1)
EP	1.42	-2.73*	2.26	-2.73*	I(1)
GDP	0.61	-3.79***	1.03	-3.85***	I(1)
Household					
ECI	-2.34	-2.98**	-1.73	-4.51***	I(1)
EP	-0.17	-3.44*	-1.28	-4.50***	I(1)
GDP	0.45	-7.81***	2.39	-9.82***	I(1)
Agricultural					
ECI	-1.08	-11.91***	-2.83	-10.33***	I(1)
EP	-2.1	-3.40**	-1.61	-3.48**	I(1)
GDP	-0.04	-7.55***	0.66	-7.86***	I(1)
Other variables					
OP	0.28	-4.88***	0.32	-4.76***	I(1)
TNTPR	-1.08	-6.81***	-1.02	-6.81***	I(1)
CU	-2.46	-6.56***	-2.46	-6.59***	I(1)

Notes: ***, ** and * indicate the level of significance at 1 per cent, 5 per cent and 10 per cent, respectively.
CU – capacity utilized; ECI – energy consumption index; EP – electricity price; OP – oil price; TNTPR – thermal and non-thermal production ratio.

Table 4 shows a long-run association of ECI_t with electricity and oil prices, real income, the thermal and non-thermal power production ratio, and the percentage of capacity utilized for electric power production. In cointegration results for aggregate, industrial and household level regressions, most of the variables are significantly different from zero and the signs of the coefficients are in alignment with economic theory and the hypothesis of this study. An exception is the result for the agricultural sector, which will be discussed later in this paper.

Table 4. Results of cointegration regressions

Dependent variable: ECI	Coefficient			
Variable	National	Industrial	Household	Agricultural
Constant	43.911***	13.698***	92.265***	13.477
EP	1.073***	0.946***	1.071	-0.349
OP	-0.155***	-0.117***	-0.208**	-0.017
GDP	-0.106***	-0.141***	-0.429***	-0.167
GDPSQ	0.0001***	0.001***	0.0006***	0.001
TNTPR	-1.820***	-1.517***	-1.241	0.299
CU	-0.057*	-0.054*	-0.125**	-0.039
R^2	0.957	0.629	0.923	0.547
Adjusted R^2	0.949	0.562	0.909	0.465
Durbin-Watson statistics	1.88	1.402	1.736	0.482
t-statistics of residual in the unit root test	-5.877***	-4.568***	-6.823***	-3.117**

Notes: ***, ** and * indicate the level of significance at 1 per cent, 5 per cent and 10 per cent, respectively.
CU – capacity utilized; ECI – energy consumption index; EP – electricity price; GDPSQ – GDP squared; OP – oil price; R^2 – the coefficient of determination is a statistical measure of how well the regression line approximates the real data points; TNTPR – thermal and non-thermal production ratio.

In a long-run equation, the price of electricity is positively correlated with ECI_t. This might be due to a decrease in electricity consumption or to an increase in oil and gas consumption as substitutes. Significant coefficients of EP_t for the national and industrial sectors refer to the fact that these sectors are highly responsive to electricity prices compared with the household sector. These results are consistent with those of Khan and Ahmed (2009) and of Chaudhry (2010), with clear implications that electricity is the primary source of energy for poor households in Pakistan. Increasing electricity prices may harm standards of living by deepening poverty. Finally, the coefficient of EP_t for the agricultural sector is insignificant, the cause of which will be discussed later in this paper.

$TNTPR_t$ consistently shows negative signs for the national, industrial and agricultural sectors, two of which are statistically significant. This result suggests some useful policy implications. To understand these implications, it is essential to recall that power generation from non-thermal sources (such as nuclear and hydroelectric sources) remains steady in Pakistan. The major change in the variable of $TNTPR_t$ comes from the expansion or shrinkage of thermal power production. Negative and significant signs of the coefficients suggest that public thermal power production for electricity can reduce the use of gas and oil for private purposes, that is, a reduction of ECI_t. In other words, an increase in the supply of electricity from public thermal power plants definitely reduces the overall consumption of oil and gas for private electricity. This is desirable because public electricity generation through power plants is more energy-efficient than privately generated electricity from backup generators.

This result further implies that there should be some governmental regulation; that is, from an energy efficiency perspective, private electricity production using backup generators should be regulated by the Government, so that the inputs of oil and gas for backup generators could be diverted to public power production. Such regulations would be consistent with policy recommendations made by Steinbuks and Foster (2010), who suggested that privately generated electricity using backup generators is very expensive and not energy-efficient due to lower fuel efficiency, compared with energy from government thermal power stations. These authors claimed that such private electricity generation must be regulated from a social planner's point of view.

Concerning the utilization of installed capacity for electricity production, the results of the present study confirm that the underutilization of this capacity is one of the major reasons for electricity shortfalls. Negative and significant coefficients of CU_t for the national, industrial and household sectors show that a higher capacity utilization would reduce ECI_t to make the country better off. In fact, Pakistan has been exploiting total power generation capacity in the range of 37 per cent to 57 per cent, as shown in figure 3 (see the CU subfigure). In 2010, only 39 per cent of the 22,263 MW of installed capacity was utilized, whereas the worst power shortfall in 2011 peaked at 6,000 MW, which is 27 per cent of total capacity (PEPCO and NTDC, 2010). The management of Pakistan's power plants could overcome this shortage by utilizing 66 per cent of this total installed capacity. The underutilization of the installed capacity supports the findings of Jamil and Ahmad (2010) in that the policies to utilize power generation capacity in an optimum way should be prioritized over policies for expanding the capacity.

Finally, with an increase in real income, negative and significant coefficients of GDP explain the fact that electricity consumption increases more than the combined consumption of oil and gas. The household sector is about four times more responsive to this change than the national and industrial sectors. This relationship seems plausible because a higher income leads to the purchase of more electronic goods, which in turn facilitate the further use of electricity. However, it should be noted that the square term of GDP_t exhibits a significant non-linear association of the positive sign with ECI_t. This means that relative electricity consumption increases faster than the combined consumption of oil and gas in GDP_t when GDP_t is not very high, holding other factors constant. However, this effect becomes reversed once GDP_t becomes sufficiently high.

To illustrate these types of non-linear effects from the regression results, the regression result in the national sector is used. The turning point in the national sector is identified as GDP* = US$ 1,127, indicating the threshold value below which GDP_t is negatively associated with a national ECI_t and above which GDP_t is positively associated with a national ECI_t. More specifically, this result implies that, if Pakistan does not improve the supply side of power generation, such as CU_t or $TNTPR_t$, the demand for oil and gas will be greater than the demand for electricity, as GDP_t exceeds the threshold value of the turning point. This is because people will be using these inputs to meet the demand for electricity by using backup generators. This result is another confirmation of the findings of Hasan, Subhani and Osman (2012) in that there will be a huge energy shortfall in Pakistan without an improvement in the power-supply systems.

Based on GDP projections data from the International Monetary Fund (2012), the real GDP of Pakistan is projected to grow by more than 3.5 per cent annually for the next five years. At this growth rate, real GDP per capita will reach the threshold value of $1,127 within the next 10 years. It is therefore necessary for the planner to take timely measures to ensure a sustainable and stable supply of electricity. Pakistan is already on the verge of national-level energy insecurity, which is illustrated by the non-linear estimation result of the study.

For the agricultural sector, although some of the signs are as expected, none of the variables is significant. There could be two main reasons for this: first, the agricultural sector does not consume natural gas; second, the model used in the study did not control the key determinant of energy demand in the agricultural sector of Pakistan. For instance, a number of environmental factors, such as cyclic floods, droughts, average annual rainfall; geographical factors, such as the elevation or the slope of the land; and modes of cultivation, such as arid, semi-arid or irrigated, play vital roles in determining the energy consumption of the agricultural sector in Pakistan. Further research is needed to determine the energy consumption of the agricultural sector in Pakistan.

In table 5, the results of the error correction models for short-run dynamics are presented. These results contain error correction terms obtained from the lagged value of stochastic error terms of cointegration equations. Negative and significant coefficients of error-correct terms confirm the existence of equilibrium in the long run, and their magnitudes represent the velocity of adjustment. Overall, the effect of significant variables is lower in the short run than in the long run. According to the results, price shocks do not affect energy consumption in the short run for any sector.

Table 5. Error correction model

Dependent variable: Δ ECI	Coefficient			
Variable	**National**	**Industrial**	**Household**	**Agricultural**
Constant	0.085	-0.078	-0.286**	-0.0043
Δ EP	-0.163	0.044	0.626	-0.076
Δ OP	-0.069	-0.045	-0.051	-0.537
Δ GDP	-0.086*	0.077	-0.103***	-0.005
Δ GDPSQ	0.0001	-0.0001	0.0001***	0.00002
Δ TNTPR	-1.813***	-0.997***	-1.034**	-0.225
Δ CU	-0.063*	-0.060***	-0.045	-0.020
$\hat{e}_{t-1}$	-1.056***	-0.794***	-0.386***	-0.253**
R^2	0.631	0.588	0.37	0.243
Adjusted R^2	0.548	0.495	0.228	0.073
Durbin-Watson statistics	2.075	1.579	1.782	2.842

Notes: ***, ** and * indicate the level of significance at 1 per cent, 5 per cent and 10 per cent, respectively.

CU – capacity utilized; ECI – energy consumption index; EP – electricity price; GDPSQ – GDP squared; OP – oil price; R^2 – the coefficient of determination is a statistical measure of how well the regression line approximates the real data points; TNTPR – thermal and non-thermal production ratio.

In fact, price changes do not affect energy demand spontaneously, which is in line with real-world observations and experiences. End consumers do not respond to sudden price changes in the short run; however, they adjust their demand in the long run. Similarly, per capita real income, $TNTPR_t$ and CU_t affect energy consumption at the national level in the long run. However, GDP_t and CU_t become insignificant in the short run at the industrial level and at the household level, respectively.

There is a high significance of the $TNTPR_t$ variable in both the long run and the short run. This result suggests the importance of thermal power production at the national level. Also, the significance of optimum electricity generation from installed capacity is confirmed in the results associated with CU_t. These results are in line with economic intuitions and illustrate that an improvement in the supply of electricity is highly linked to ECI_t in short-run and long-run perspectives.

Using the aforementioned results, it is possible to answer the questions raised in section I of this paper. The first and second questions were: “How do energy end users behave in response to changes in the supply side and other socioeconomic factors?” and “What is the cause of the power shortages?” The results suggest that end users do not respond to price changes, at least in the short run, although they adjust their consumption in the long run. This implies that the price adjustment tactics that have been implemented by the Government are ineffective since this policy is oriented towards easing energy shortages only in the short run.

Regarding end users' responses to a change in the supply side and the cause of the power shortages, changes in CU_t and $TNTPR_t$ were the focus. As expected, an increase in CU_t comes with a reduction in ECI_t, meaning that if power suppliers utilized more of their operational capacities, it could contribute to easing power shortages or reducing the reliance on backup generators. A change in $TNTPR_t$ is mainly driven by thermal electricity generation. Historically, a decrease in $TNTPR_t$ comes with a decrease in thermal electricity generation, and an increase in $TNTPR_t$ occurs with an increase in thermal electricity generation. Considering the facts, the study results are estimated to show that ECI_t decreases in $TNTPR_t$, implying that a greater utilization of thermal plants could reduce the use of backup generators. This implication sounds counter-intuitive at first; however, it is plausible from an energy efficiency perspective. It is not questionable that large-scale thermal power plants are far more energy-efficient than backup generators per unit of oil or gas input. In other words, thermal power plants can generate more electricity per input than backup generators.

Lastly, the answer to the final question from section I ("What policy would be effective in solving the energy shortage problem?") can be provided. Given the arguments up to this point, it is recommended that the Government should focus on the greater utilization of existing power plants in terms of capacity utilization as well as total electricity generation, as illustrated by the negative coefficients of statistical significance on CU_t and $TNTPR_t$ in tables 4 and 5. Unfortunately, the Government has failed to use this type of policy; rather, it has adopted price adjustment tactics, which were shown to be ineffective in the study's estimation results. There appear to be some political and socioeconomic barriers within the energy supply preventing the implementation of the policy recommendations provided in the present paper. However, without the greater utilization of the existing power plants' installed capacities, energy shortages in Pakistan will worsen as the economy grows. Looking at contemporary energy shortage problems in many Asian countries with growing economies, such as China and India, the use of backup generators for private energy is problematic, as they are a source of emissions. The framework used in the present paper is also applicable to such countries. More specifically, the greater utilization of public power plants is necessary to reduce the use of backup generators, and some regulation must be made for private electricity generation to improve social welfare in Pakistan with respect to energy consumption.

V. CONCLUSION

The relationships between energy consumption, prices, real income, the effects of power generation from different sources and the utilization of total installed capacity for power production were investigated in this study by using cointegration and error correction models. The annual data for the national level as well as for major sectors of the economy – namely industrial, household and agricultural – were examined for the period 1971-2010. The main findings were as follows: first, end consumers adjust their energy demand to the prices only in the long run; second, the underutilization of installed power-generation capacity encourages fossil fuel consumption for private electricity; third, an uninterrupted electricity supply could be attained by regulating private electricity generation; and fourth, the relative demand for electricity shows a non-linear relationship to oil and gas.

Overall, the study results imply that the price adjustment tactics adopted by the Government of Pakistan are not effective in the short run. Rather, the Government should focus on improving the utilization rate of installed power plants and on rechannelling the use of oil and gas for public electricity generation. Otherwise, energy shortages will worsen with economic growth in Pakistan, and the economy will suffer from welfare loss. Over the past decade, the energy policy of Pakistan has been focused on expanding production capacity through RPPs to address electricity shortages. The present study suggests that policies for the optimum utilization of the existing electricity generation capacity should be prioritized over the installation of new power plants. The Government should also make the best utilization of scarce natural gas and expensive oil resources.

Finally, some limitations of this study need to be acknowledged. First, the model does not work for the agricultural sector because there could be several missing factors determining agricultural energy consumption, such as the environment, climatic conditions, different modes of irrigation and geographical characteristics. Future studies to investigate the power shortage dynamics in the agricultural sector must incorporate these important factors. In addition, the analysis done in the present study relies on the index of energy shortages from the macro level. To strengthen the findings, a further study should be conducted to analyse energy consumption behaviour in Pakistan from the micro level or the household level.

REFERENCES

Adenikinju, A. (2005). Analysis of the cost of infrastructure failures in a developing economy: the case of the electricity sector in Nigeria. AERC Research Paper, No. 148. Nairobi: African Economic Research Consortium.

Ahmad, S. (2010). Myth and reality of rental power plants. *Pakistan Observer,* 1 December.

Ahmadani, A. (2013). KESC decides to convert two power plants from oil to coal. *Nation,* 11 September.

Amer, M., and T.U. Daim (2011). Selection of renewable energy technologies for a developing county: a case of Pakistan. *Energy for Sustainable Development*, vol. 15, No. 4 (December), pp. 420-435.

Aqeel, A., and M.S. Butt (2001). The relationship between energy consumption and economic growth in Pakistan. *Asia-Pacific Development Journal*, vol. 8, No. 2, pp. 101-110.

Asian Development Bank (ADB) (2010). *Islamic Republic of Pakistan: Rental Power Review*. Manila.

Beenstock, M. (1991). Generators and the cost of electricity outages. *Energy Economics*, vol. 13, No. 4 (October), pp. 283-289.

Beenstock, M., E. Goldin, and Y. Haitovsky (1997). The cost of power outages in the business and public sectors in Israel: revealed preference vs. subjective valuation. *Energy Journal*, vol. 18, No. 2, pp. 39-61.

Bhatti, M.W. (2012). KESC fears backlash over hike in furnace oil prices. *News International*, 17 August.

Bhutto, A.W., and S. Karim (2007). Energy-poverty alleviation in Pakistan through use of indigenous energy resources. *Energy for Sustainable Development*, vol. 11, No. 1 (March), pp. 58-67.

Carlsson, F., and P. Martinsson (2008). Does it matter when a power outage occurs? A choice experiment study on the willingness to pay to avoid power outages. *Energy Economics*, vol. 30, No. 3 (May), pp. 1232-1245.

Carlsson, F., P. Martinsson, and A. Akay (2011). The effect of power outages and cheap talk on willingness to pay to reduce outages. *Energy Economics*, vol. 33, No. 5 (September), pp. 790-798.

Chaudhry, A.A. (2010). A panel data analysis of electricity demand in Pakistan. *The Lahore Journal of Economics*, vol. 15, special edition (September), pp. 75-106.

Dickey, D.A., and W.A. Fuller (1981). Likelihood ratio statistics for autoregressive time series with a unit root. *Econometrica*, vol. 49, No. 4, pp. 1057-1072.

Dzioubinski, O., and R. Chipman (1999). Trends in consumption and production: household energy consumption. Department of Economic and Social Affairs, DESA Discussion Paper, No. 6. New York: United Nations.

Engle, R.F., and C. Granger (1987). Co-integration and error correction: representation, estimation, and testing. *Econometrica*, vol. 55, No. 2 (March), pp. 251-276.

Gillani, Q.F., and others (2011). A step for the future sustainability in Pakistan: conversion of vehicle fuel from CNG to HCNG and its environmental effects/benefits. *International Journal of Chemical and Environmental Engineering*, vol. 2, No. 3 (June), pp. 180-182.

Hasan, S.A., M. Imtiaz Subhani, and A. Osman (2012). The energy short fall and its after effects (a case study for Karachi city in context to Karachi Electric Supply Corporation). *Science Series Data Report*, vol. 4, No. 2, pp. 42-49.

International Monetary Fund (2012). *World Economic Outlook: Growth Resuming, Danger Remains.* Washington, D.C.

Jamil, F., and E. Ahmad (2010). The relationship between electricity consumption, electricity prices and GDP in Pakistan. *Energy Policy*, vol. 38, No. 10 (October), pp. 6016-6025.

Kessides, C. (1993). The contributions of infrastructure to economic development: a review of experience and policy implications. Discussion Paper, No. 213. Washington, D.C.: World Bank.

Kessides, I.N. (2013). Chaos in power: Pakistan's electricity crisis. *Energy Policy*, vol. 55, pp. 271-285.

Khan, M.A., and U. Ahmed (2009). Energy demand in Pakistan: a disaggregate analysis. MPRA Paper, No. 15056. Munich: University Library of Munich.

Khan, N.A., and H. el Dessouky (2009). Prospect of biodiesel in Pakistan. *Renewable and Sustainable Energy Reviews*, vol. 13, Nos. 6 and 7, pp. 1576-1583.

Kucukali, S., and K. Baris (2010). Turkey's short-term gross annual electricity demand forecast by fuzzy logic approach. *Energy Policy*, vol. 38, No. 5 (May), pp. 2438-2445.

Lodhi, R.N., and R.K. Malik (2013). Impact of electricity shortage on daily routines: a case study of Pakistan. *Energy and Environment*, vol. 24, No. 5 (September), pp. 701-710.

Lodhi, R.N., M.A. Siddiqui, and U. Habiba (2013). Empirical investigation of the factors affecting foreign direct investment in Pakistan: ARDL approach. *World Applied Sciences Journal*, vol. 22, No. 9, pp. 1318-1325.

Mills, E. (2012). Pakistan's energy crisis. Peaceworks, No. 79. Washington, D.C.: United States Institute of Peace.

de Nooij, M., C. Koopmans, and C. Bijvoet (2007). The value of supply security: the costs of power interruptions – economic input for damage reduction and investment in networks. *Energy Economics*, vol. 29, No. 2 (March), pp. 277-295.

de Nooij, M., R. Lieshout, and C. Koopmans (2009). Optimal blackouts: empirical results on reducing the social cost of electricity outages through efficient regional rationing. *Energy Economics*, vol. 31, No. 3 (May), pp. 342-347.

Pakistan Electric Power Company (PEPCO) and National Transmission and Despatch Company (NTDC) (2010). Electricity marketing data. Technical report. Lahore: Pakistan Water and Power Development Authority.

Pakistan, Ministry of Finance (2007). Energy. In *Statistical Supplement of Economic Survey 2006-07*. Islamabad.

________ (2010). Energy. In *Pakistan Economic Survey 2009-10*. Islamabad.

________ (2011). Energy. In *Pakistan Economic Survey 2010-11*. Islamabad.

________ (2013). *Pakistan Economic Survey 2012-13*. Islamabad.

Pakistan, Ministry of Water and Power (2013). *National Power Policy 2013.* Islamabad.

Pakistan, National Electric Power Regulatory Authority (2004). Determination of tariff in respect of review motion/petition filed on 22nd June 2004 by M/s. Faisalabad Electric Supply Co., Ltd. Islamabad.

________ (2013). Decision of the authority regarding request for reconsideration of tariff determinations pertaining to ex-WAPDA distribution companies for the financial year 2012-13 under Section 31(4) of NEPRA Act 1997. Islamabad.

Pasha, H.A., A. Ghaus, and S. Malik (1989). The economic cost of power outages in the industrial sector of Pakistan. *Ecological Economics*, vol. 11, No. 4, pp. 301-318.

Reichl, J., M. Schmidthaler, and F. Schneider (2013). The value of supply security: the costs of power outages to Austrian households, firms and the public sector. *Energy Economics*, vol. 36, pp. 256-261.

Sanghvi, A.P. (1982). Economic costs of electricity supply interruptions: US and foreign experience. *Energy Economics*, vol. 4, No. 3 (July), pp. 180-198.

________ (1983). Optimal electricity supply reliability using customer shortage costs. *Energy Economics*, vol. 5, No. 2, pp. 129-136.

Serra, P., and G. Fierro (1997). Outage costs in Chilean industry. *Energy Economics*, vol. 19, No. 4 (October), pp. 417-434.

Shakil-ur-Rahman, Mir, ed. (2012). Summary of SC judgment in rental power plants case. *News International*, 31 March. Available from www.thenews.com.pk/Todays-News-6-100407-Summary-of-SC-judgment-in-Rental-Power-Plants-case.

Shoaib, M. (2013). Energy. In *Pakistan Economic Survey 2012-13*. Islamabad: Pakistan, Ministry of Finance.

Siddiqui, R. (2004). Energy and economic growth in Pakistan. *Pakistan Development Review*, vol. 43, No. 2, pp. 175-200.

Steinbuks, J., and V. Foster (2010). When do firms generate? Evidence on in-house electricity supply in Africa. *Energy Economics*, vol. 32, pp. 505-514.

Supreme Court of Pakistan (2010). Human rights case no. 7734-G/2009 and 1003-G/2010. Islamabad. Available from www.supremecourt.gov.pk/web/user_files/File/HRC7734-G_1003-GOF2009[AllegedCorruptionInRentalPowerPlants].pdf.

Szakonyi, D., and J. Urpelainen (2013). Electricity sector reform and generators as a source of backup power: the case of India. *Energy for Sustainable Development*, vol. 17, No. 5, pp. 477-481.

Tishler, A. (1993). Optimal production with uncertain interruptions in the supply of electricity: estimation of electricity outage costs. *European Economic Review*, vol. 37, No. 6, pp. 1259-1274.

Transparency International – Pakistan (2010). Executive summary of rental power projects. Karachi.

Water and Power Development Authority (WAPDA) (2011). *Electricity Marketing Data: Power System Statistics 2010,* 36th ed. Lahore, Pakistan. Available from www.ntdc.com.pk/Files/emd.pdf.

Wijayatunga, P.D., and M.S. Jayalath (2008). Economic impact of electricity supply interruptions on the industrial sector of Bangladesh. *Energy for Sustainable Development*, vol. 12, No. 3, pp. 5-12.

World Bank. World Development Indicators. Available from http://data.worldbank.org/country/pakistan.

Yazdanie, M., and T. Rutherford (2010). Renewable energy in Pakistan: policy strengths, challenges and the path forward. Centre for Energy Policy and Economics, Swiss Federal Institute of Technology Zurich, Switzerland.

Younos, T., R. Hill, and H. Poole (2009). Water dependency of energy production and power generation systems. VWRRC Special Report, No. SR46-2009. Blacksburg, Virginia: Virginia Polytechnic Institute and State University.

Zeshan, M. (2013). Finding the cointegration and causal linkages between the electricity production and economic growth in Pakistan. *Economic Modelling*, vol. 31, pp. 344-350.