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Energy Demand in Pakistan: A Disaggregate Analysis

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Abstract: This study examines the demand for energy at disaggregate level (gas, electricity and coal) for Pakistan over the period 1972-2007. Over main results suggest that electricity and coal consumption responds positively to changes in real income per capita and negatively to changes in domestic price level. The gas consumption responds negatively to real income and price changes in the short-run, however, in the long-run real income exerts positive effect on gas consumption, while domestic price remains insignificant. Furthermore, in the short-run the average elasticities of price and real income for gas consumption (in absolute terms) are greater than that of electricity and coal consumption. The differences in elasticities of each component of energy have significant policy implications for income and revenue generation.

Introduction

Energy is considered to be the life line of an economy, the most vital instrument of socioeconomic development and has been recognized as one of the most important strategic commodities (Sahir and Qureshi, 2007). Energy is not only essential for the economy but its supply is uncertain (Zaleski, 2001). Energy is a strategic source that influenced the outcomes of wars, fueled and strangled economic development and polluted as well as clean up the environment.

In the era of globalization, a rapidly increasing demand for energy and dependency of countries on energy indicate that energy will be one of the biggest problems in the world in the next century. This requires for alternative and renewable sources of energy. Traditional growth theories focus much on the labour and capital as major factor of production and ignore the importance of energy in the growth process (Stern and Cleveland, 2004). The neo-classical production theories stresses that economic growth increases with the increases in labour, capital and technology. Today energy is indispensable factor and plays an important role in the consumption as well as production process.¹ Research suggests that energy plays an important role as compared to other variables included in the production and consumption function for countries which are at intermediate stages of economic development (IEA, 2005). When we examine disaggregating components of energy demand, it is seen that electricity is the highest quality energy component and its share in energy consumption increases rapidly. Natural gas, petroleum and coal follow electricity respectively. This idea is supported by the results obtained when energy prices per unit are taken into consideration (Stern and Cleveland, 2004 and Erbaykal, 2008).

The decisions of households and businesses regarding the use of energy have very important implications for long-run as well as short-run changes in economic activities. The nature of the demand for energy and the knowledge of its determinants are of crucial importance for accurate forecasting of its current and future needs. For this reason it is necessary to examine the nature of the relationship between energy consumption, output and the prices. The analysis is also

¹ In this paper we have used energy demand and energy consumption interchangeably.

important for the assessment of expenditures on energy consumption, energy demand management and development of strategies for future energy requirements.

Given the paramount importance of energy in the consumption patterns and productive activities, we examine the energy demand function at disaggregate level in the Pakistan over the period 1972-2007 using multivariate cointegration approach developed by Johansen (1988) and Johansen and Juselius (1990). In Pakistan, the economic structure, consumption patterns, available technologies, transport and rural-urban structure and life style that are generally different from those of well-developed countries. This situation demands the estimation of income and price elasticities of demand of each type of energy consumption, which indicate the possibilities and limitations of alternative energy control policies.

The relationship between energy consumption and economic growth has important implications at the theoretical, empirical and policy level. A large number of studies have focused on the relationship between energy consumption and real output. However, to date the results are mixed and conflicting. The variation in empirical findings could be due to different economic structure of particular countries being studied (Sari *et al.*, 2008). Another reason may be due to the fact that different economies have different consumption pattern and various sources of energy. Therefore, different sources of energy consumption might have varying impacts on the output of an economy (Ozun and Cifter, 2007). Kraft and Kraft (1978) has found unidirectional causality running from GNP to energy consumption for United States for the period between 1947 and 1974. Their results indicates that the low level of energy dependence of US economy on energy enable US to pursue energy conservation policies which have no adverse effects on income (Jumbe, 2004). Akarca and Long (1980) tested this relationship using the same data set for the USA and could not find relationship between the variables. Similar results were also found by found by Yu and Hwang (1984), Yu Choi (1985), Erol and Yu (1987), Yu and Jin (1992), Cheng (1995), Asafu-Adjaye (2000), Soytas and Sari (2003), Altinay and Karagol (2004), Wolde-Rufael (2005), Lee (2006) and Soytas and Sari (2006). Erol and Yu (1987) examined the relationship between energy consumption and GDP for England, France, Italy, Germany, Canada and Japan for the period 1952-1982. They found bidirectional causality for Japan, unidirectional causality from energy consumption to GDP for Canada and unidirectional causality from GDP to

energy consumption for Germany and Italy and no causality for France and England. In the context of developing countries Masih and Masih (1996) found evidence of Granger causality running from income to energy for Indonesia.

In contrast, the studies *inter alia* by Fatai *et al.* (2004), Stern (1993, 2000), Yu and Choi (1985), Soytaş *et al.* (2001), Soytaş and Sari (2003), Asafu-Adjaye (2000), Wolde-Rufael (2004) and Lee (2005) found supportive evidence of causality running from energy consumption to income. However, many researchers have reported that the relationship between energy-income may be characterized bi-directional causality. For example, Erol and Yu (1987) reported bi-directional causality for Italy and Japan and similar results are reported by Hwang and Gum (1992) for Taiwan, Masih and Masih (1996) for Pakistan, Soytaş and Sari (2003) for Argentina, Ghali and El-Sakka (2004) for Canada, Wolde-Rufael (2005) for Gabon and Zambia, Lee for US and Asafu-Adjaye (2000) for Thailand and Philippines. Siddiqui (2004) concludes that the impact of all sources of energy were not same on economic growth. The impact of electricity and petroleum products were high and significant on economic growth with reverse causality between petroleum products and economic growth. Paul and Bhattacharya (2004) examined causality between energy consumption and economic growth for India over the period 1950-1996 applying both Engle and Granger (1987) and Johansen (1988) cointegration approach. The results supported the evidence of unidirectional causality from energy consumption to economic growth. Results based on Engle-Granger cointegration test exhibited unidirectional causality running from GDP to energy consumption in the long-run and no causality evidence was found in the short-run. They pointed out that when Engle-Granger approach combined with standard Granger causality test, the evidence of bi-directional causality between energy consumption and economic growth was found. The authors concluded that the long-run causal relation running from GDP to energy consumption and the short-run causal relation running from energy consumption to GDP.

At disaggregate level Ghosh (2002) have examined economic growth and electricity consumption for India over the period 1950-1997 and found unidirectional causality from economic growth to electricity. Jumbe (2004) has found bidirectional causality between GDP and electricity for Malawi over the period 1970-1999. However, when he examined the

relationship between non-agriculture GDP and electricity consumption, he found unidirectional causality running from GDP to energy. Rufael (2006) find cointegration in nine countries and Granger causality for twelve countries. He found that the causality running from GDP to electricity consumption in six countries and from electricity consumption to GDP in three countries and bidirectional causality in three countries. Zou and Chau (2005) found no cointegration between oil consumption and GDP in China over the period 1983-2002. In the context of Pakistan only two studies are available that analyses the energy at disaggregate level (i.e. Siddiqui and Haq (1999) and Aqeel and Butt (2001)). Siddiqui and Haq (1999) analyzes the demand for different sources of energy and finds that energy demand in general is price elastic and changes in income also affect energy demand significantly. They concluded that changes in own price and prices of other components of energy has limited impact on revenue generation due to their impact on inflation, income distribution and political and social conditions of the country. Aqeel and Butt (2001) find that economic growth causes total energy consumption at aggregate level. A disaggregate level, they finds unidirectional causality from economic growth to petroleum consumption, but no causality between economic growth and gas consumption and unidirectional causality from electricity consumption to economic growth. From the survey of empirical literature we come to the conclusion that although these studies have made significant contributions regarding the relationship between energy consumption and economic growth, but not sufficiently shed lights on the dynamic insights of the sources of energy consumption, real income and domestic price level. This study analyzes the sectoral relationship viz., petroleum, gas, electricity and coal consumption with that of real GDP and domestic price level for Pakistan over the period 1972-2007. Many previous studies have either ignored need for testing the time series properties of the variables entering in the energy-growth relationship or used Engle and Granger (1987) single equation methodology. This methodology presupposes that all the variables contain a unit root. The complexity of relationship among energy consumption and real income and domestic price level requires a reexamination of long-term and short-term linkages between energy consumption, real output and domestic price level using multivariate cointegration method.

The rest of this paper is organized as follows: Section 2 shed lights on the energy market in Pakistan. Model, methodology and data are discussed in section 3. Empirical results and their

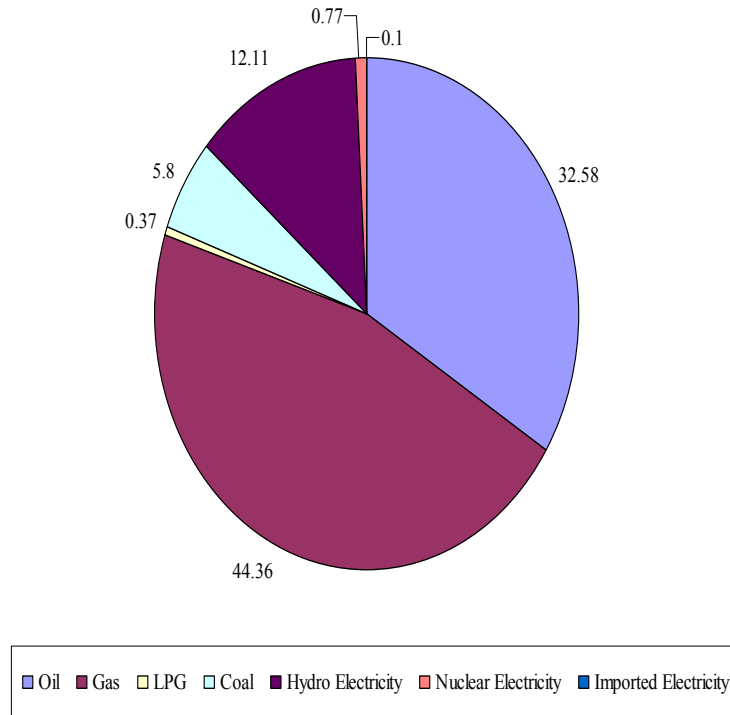
interpretation are given in section 4, while concluding remarks and policy implications are given in the final section.

2. Energy Sector in Pakistan

Pakistan's energy infrastructure is under-developed, insufficient and poorly managed.² Presently Pakistan has been facing severe energy crisis. Despite strong economic growth and rising energy demand during the past decade, no serious efforts have been made to install new capacity of generation. Consequently, the demand exceeds supply and hence load-shedding is a common phenomenon through power shutdown (Haq and Hussain, 2008). Pakistan needs around 14,000 to 15,000 MW electricity per day, and the demand is likely rise to approximately to 20,000 MW per day by 2010. Presently, it can produce about 11,500 MW per day and there is a shortfall of about 3000 to 4000 MW per day. This shortage is badly affecting industry, commerce, daily life and posing risks to the economic growth (Haq and Hussain, 2008). The overall requirement of Pakistan is expected to be about 80 MTOE in 2010, up by 50% from the 54 MTOE of the current year. During the past 25 years energy supply in Pakistan has been increased by about 40 times but still the demand outstrips supply. With the increase in economic activities, per capita energy consumption had also been increased. Industrialization, growth in agriculture and services sectors, urbanization, rising per capita income and rural electrification has resulted in a phenomenal rise in energy demand (NBP, 2008). Inefficient use of energy and its wastages has further widened the demand-supply gap and exerts strong pressure on the energy resources in the country. The annual growth of primary energy supply increased from 3.17% to 4.3% during 1997-98 to 2006-07. The share of natural gas reached to 48.5%, followed by oil 30.0%, hydro electricity 12.6%, coal 7.3%, nuclear electricity 0.9%, LPG 0.5% and imported electricity by 0.1% during the year 2006-07. Figure 1 presents the shares of primary energy supply in Pakistan.

² The energy sector of Pakistan is poorly managed, service quality is low, theft of power and gas is rampant and most utilities are still receiving subsidies.

Figure 1: Percentage Share of Primary Energy Supply from 1997-98 to 2006-07 (in TOE)



It can be clear from Figure 1 that energy supply in Pakistan is highly dependent on Oil and Gas, which together contributes more than 77% of the total primary energy supplied. The average share of gas and oil are respectively 44.36% and 32.58% during the period 1997-98 to 2006-07. The remaining sources of energy supply consist of hydro- electricity and coal and their shares in total energy supply are around 12% and 6% respectively during the corresponding period. During 2006-07, total primary energy supply was 60387776 TOE. However, the energy supply for the final consumption is equal to 36005255 TOE.

It is now globally recognized that energy plays an important role in the production process. In Pakistan, agriculture, industry, trade and services sectors have been growing rapidly over the past few years. Given the pace of economic growth, energy demand is expected to increase. During

the 1980s about 86% of the energy demand was met by domestic sources of energy and remaining 14% gap was filled by the imports. Since then, the demand-supply gap has been widening and reached around 47% by the end of 2000 (SBP, 2006).

At present Pakistan meets 75% of its energy needs by domestic resources including gas, oil and hydroelectricity production. Only 25% energy needs were managed through imports and Oil taken major share alone and imported oil may likely maintain important share in the future energy mix. Natural gas has emerged as the most important fuel in the recent past and the trends indicate its dominant share in the future energy mix (Sahir and Qureshi, 2007). To sustain the pace of economic growth rate of over 7% over the next 25 year, Pakistan needs to expand its energy resource base. Figure 2 highlights the percentage share of the source-wise energy consumption in Pakistan during the period 1997-98 to 2006-07.

Figure 2: Share of Source-wise Energy Consumption during 1997-98 to 2006-07 (in % of total TOE)

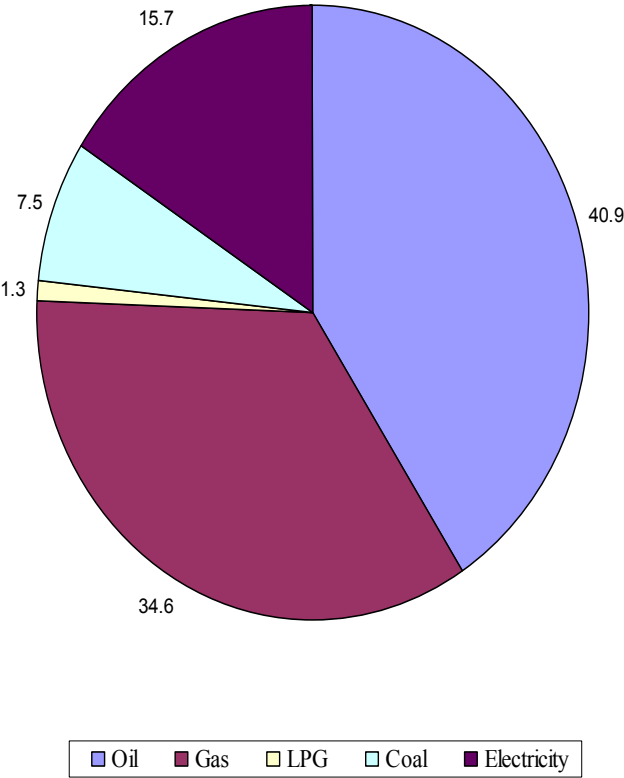
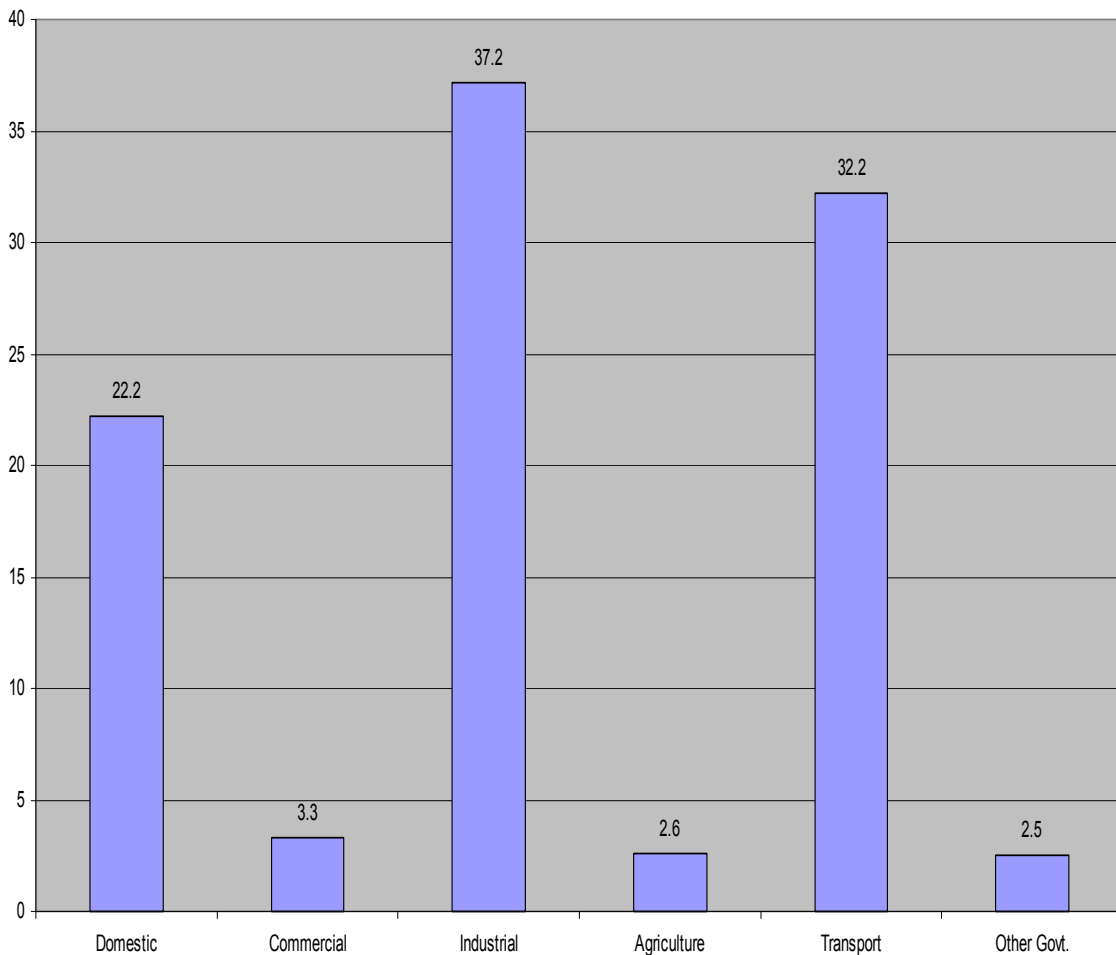


Figure 2 suggest that the average percentage share of oil in energy consumption was 40.9% during 1997-98 to 2006-07, followed by gas 34.6%, electricity 15.7%, coal 7.5% and LPG 1.3% during the same period. Significant changes took place among the inter-sectoral patterns of energy consumption. The change in pattern is evident from the data presented in Figure 3. It is evident from Figure 3 that on average industrial sector consumed 37.3% of energy, followed by transport sector with share 32.2% and domestic sector with share 22.2%. The agriculture sector, government and the commercial sector respectively consumed 2.6%, 2.5% and 3.3%. Though the annual growth rate of energy

Figure 3: Energy Consumption by Sector (% of total energy)



consumption has come down from 10.8% in 2004-05 to 6.1% at the end of 2006-07, still at present Pakistan faces deep energy crisis due to demand-supply gap. To steer the economy out of this crisis and to meet the future challenges there is urgent need to expand and upgrade the domestic resource base, accelerate exploitation and exploration of additional indigenous resources, increase the share of coal and hydroelectric in the energy mix, promote alternative renewable energy sources, improve energy efficiency and conservation, promote public private partnership in the energy sector and insure the necessary human resource development.

The per capita consumption of energy by different sources of energy is reported in Table 1. It is clear from the Table 4 that per capita consumption of oil during 1997-98 to 2003-04 fell from 4.0 kg to 1.6 kg, whereas per capita consumption of natural gas stood

Table 1: Per capita Household Energy Consumption

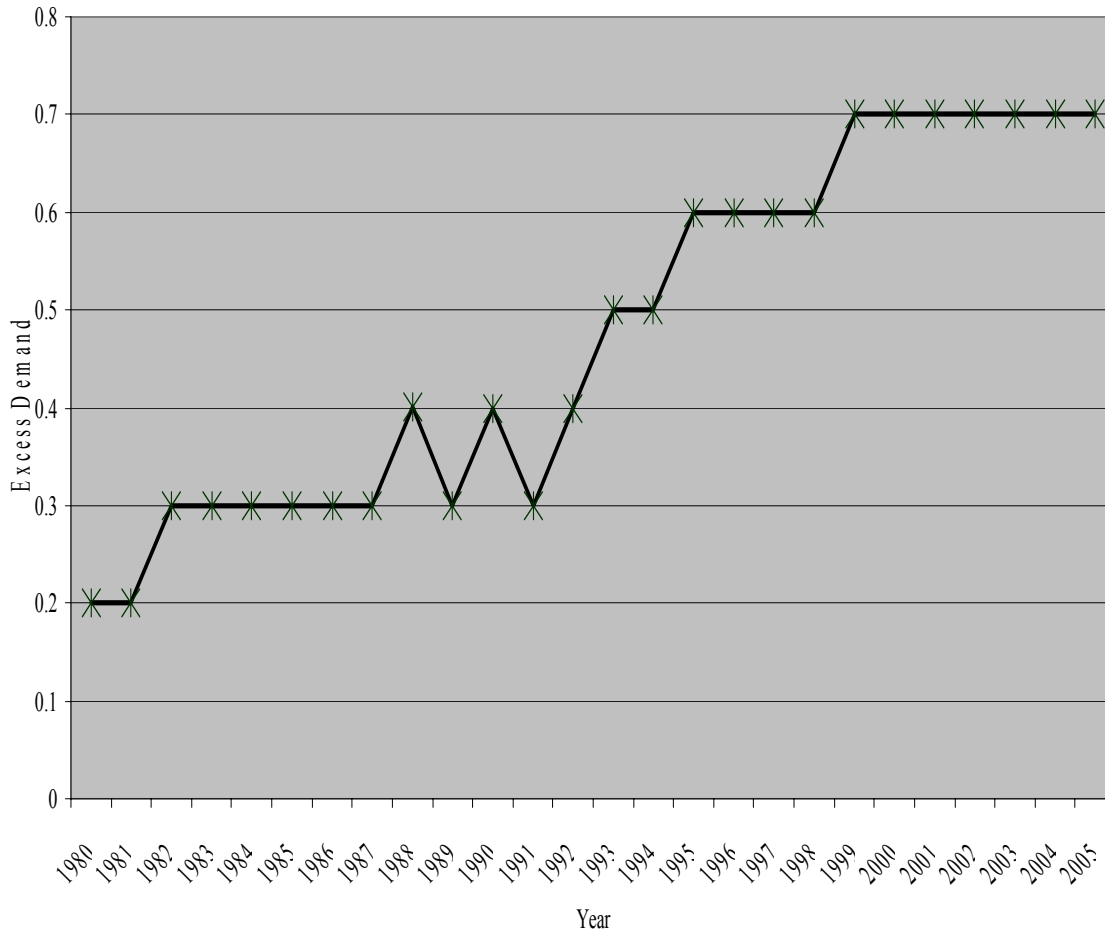
Parameter	1997-98	1998-99	1999-00	2000-01	2001-02	2002-03	2003-04
Population (in million)	113	133	136	140	143	147	150
Oil (kg)	4.0	3.8	3.6	3.3	2.4	2.0	1.6
Gas (MMBtu)	1.0	1.0	1.0	1.0	1.0	1.0	1.0
LPG (kg)	1.2	1.2	1.3	1.4	1.8	1.8	1.9
Electricity (kWh)	114	146	157	163	162	161	172

Source: Household Use of Commercial Energy (Report No. 320/06, World Bank)

constant at 1.0 (MMBtu). The per capita consumption of LPG and electricity shows an increasing trend. Pakistan's economy has been growing at an average of 7.6% per year over the last three years. To sustain future growth of over 7%, the demand for energy is expected to grow at 1.2 times the economic growth rate, amounting to over 8% growth per year (ISSI, 2007b).³ However, the excess demand for energy has been increasing year-by-year and creating alarming situation for the country (Looney, 2007). It is clear from the Figure 4 that of the excess demand for energy has increased overtime. The average excess demand for energy is equal to 0.48 QBtu for the period 1980-2005. According to Pakistan's Energy Security Plan (2005-2030), the total primary energy consumption in Pakistan is expected to increase seven-fold from 55 MTOE to 360 MTOE and over eight-fold increase in the requirement of power by 2030 (ISSI, 2007b).

³ ISSI represents "The Institute of Strategic Studies", Islamabad.

Figure 4: Excess Demand for Energy since 1980-2005 (in Quadrillion Btu)



Thus the country would be facing the shortage of more than 31% of energy in the future. In Pakistan the current energy crisis stems from the decline in hydro sources of energy and over-reliance on the expansive source of electricity. Presently, oil-based thermal plants accounts for 68% of generating capacity, hydroelectric plants for 30% and nuclear plants for only 2% (Looney, 2007). This has led to a huge generation costs, which in turn adversely affect the economy over the past eight years. Rise in the oil prices pushing electricity tariff very high. As a result, manufacturing costs and inflation are at the rising trend, export competitiveness is eroded and the pressure on the balance of payments is increasing. These factors adversely affect the present growth trajectory of the economy (Loonely, 2007 and NBP, 2008).

3. Model, Methodology and Data

The Energy demand is function of various factors such as real income, relative prices and structure of the economy, the available technology and life style (Howard et al. 1993 and Jorgenson and Wilcoxon, 1993). However, energy demand studies frequently employs GDP and energy price as an argument to calculate income and price elasticities. These elasticities have been used to understand demand behaviour, demand management, energy forecast and policy analysis (Varian, 1988). The estimated elasticities have relevant for designing appropriate pricing policies. Following the conventional neo-classical microeconomic theory (Bentzen and Engsted (1993), Mohammad and Eltony, 1996, Beenstock *et al.* (1999), Clements and Madlener (1999), Silk and Joutz (1997), Al-Faris (2002), Narayan and Smyth (2005), De Vita *et al.* (2006), Dergiades and Tsoulfidis (2008) and Ziramba (2008)) the demand for energy is modeled as the outcome of a utility maximization process undertaken by consumers. The solution of utility maximization problem yields the following general demand function.

$$q_t^j = \beta_0 + \beta_1 r y_t + \beta_2 p_t + \varepsilon_t \quad (1)$$

Where q_t , $r y_t$ and p_t are respectively per capita energy consumption, per capita real income and domestic price level at time t . ε_t is the random term assumed to be normal and identically distributed.⁴ $j = E, G, P$ and C denote the electricity, gas, petroleum and coal consumption respectively. The lower case letters represents the logarithmic values of the variables included in equation (1). The coefficients β_1 and β_2 represents the elasticities of real output per capita and price level.

We employ Johansen (1988) and Johansen and Juselius (1990) multivariate cointegration method to examine the cointegration between various components of energy, real output per capita and price level. We will not offering a detailed explanation of Johansen's methodology because it has well documented in the existing literature. If the null of no cointegration is rejected, then we estimate the dynamic energy demand model by using the following error-correction model:

⁴ Lower case letters denote that the variables are expressed in logarithms.

$$\Delta q_t^j = \beta_0 + \sum_{i=1}^k \gamma_{1i} \Delta q_{t-i}^j + \sum_{i=1}^k \beta_{1i} \Delta r y_{t-i} + \sum_{i=1}^k \beta_{2i} \Delta p_{t-i} + \lambda(q_{t-1}^j - \beta_0 - \beta_1 r y_{t-1} - \beta_2 p_{t-1}) + u_t \quad (2)$$

such that $\lambda \neq 0$

If the null of no cointegration is not rejected, then we employ short-run vector autoregressive (VAR) Granger causality/block exogeneity Wald test by estimating the following equation

$$\Delta q_t^j = \beta_0 + \sum_{i=1}^k \gamma_{1i} \Delta q_{t-i}^j + \sum_{i=1}^k \beta_{1i} \Delta r y_{t-i} + \sum_{i=1}^k \beta_{2i} \Delta p_{t-i} + u_t \quad (3)$$

such that $\beta_{1i}, \beta_{2i} \neq 0$

The study is based on annual data covering the period 1972-2007. Data on per capita electricity consumption (Gwh), per capita petroleum consumption (tones), per capita consumption of natural gas (mm cft excluding LPG) and per capita coal consumption (thousand of metric tone) are calculated as each source of energy divided by population. Real income is calculated as nominal GDP divided by consumer price index (2000=100). Real income per capita is calculated as real income divided by population. Since the data on prices of each source of energy is not available, we proxied it by the consumer price index (see Asafu-Adjaye, 2000; Hondroyiannis *et al.*, 2002; Akinlo, 2008 and Galindo, 2005). Data on energy sources are taken from *Pakistan Economic Survey* (various issues) and data on GDP, CPI and population are taken from *International Financial Statistics* (i.e., *IFS CD-ROM- 2008*)

4. Empirical Analysis

We first examine the order of integration using Augmented Dickey-Fuller (ADF) unit root test. Table 2 report the results.

Table 2: Augmented Dickey-Fuller (ADF) Tests

Series	Optimum Lag	$t - ADF$	β	σ	$t - \Delta Y$ lag	AIC	Decision
ry_t^T	0	-1.167	0.863	0.037	-	-6.506	I (1)
p_t	0	-0.8633	-0.006	0.018	-	-4.873	I (1)
pol_t	2	-1.586	0.052	0.063	2.009	-2.591	I (1)
gas_t	1	-0.731	0.981	0.042	1.781	-6.226	I (1)
$elec_t$	0	-2.444	0.964	0.035	-	-6.460	I (1)
$coal_t$	3	-2.438	0.487	0.101	2.044	-4.411	I (1)
Δry_t	0	-5.400*	-0.015	0.038	-	-6.454	I (0)
Δp_t	0	-3.106**	-0.318	0.028	-	-4.250	I (0)
Δpol_t	1	-2.598	-0.637	0.064	-2.598	-2.568	I (1)
Δgas_t	0	-3.645*	0.325	0.043	-	-6.250	I (0)
$\Delta elec_t$	1	-2.661***	0.416	0.035	-1.955	-6.588	I (0)
$\Delta coal_t$	0	-6.816*	-0.241	0.108	-	-4.386	I (0)

Optimum lag equation for ADF : $\Delta x_t = \alpha + \mu t + \beta x_{t-1} + \sum_{i=1}^p \gamma_i \Delta x_{t-i} + v_t$

Note: (a) Optimum lag is based on minimized Akaike Information Criterion (AIC). T stands for time trend.

(b) The results for the first difference variables are reported without trend.

We started with 4 lags and tested down to zero lag and selected the model using the optimum lags and no serial correlation in the residuals. The t -ADF column gives the values of the test and if these are higher than critical values in absolute terms, the unit root hypothesis is rejected. The results suggest that except per capita consumption of petroleum (pol_t) all other variables are stationary at their first difference, implies that all the series are integrated of order one (i.e. $I(1)$). Per capita consumption of petroleum (pol_t) remains non-stationary at its first difference, implies that this variable is integrated of order two (i.e. $I(2)$). Based on the results of unit root test we estimates natural gas, electricity and coal demand functions for Pakistan using Johansen (1988) and Johansen and Juselius (1990) multivariate cointegration method to determine the long-run relationship among $I(1)$ variables.

(i) Natural Gas Demand Function

Natural gas has become an important and largest source of energy in Pakistan with demand and imports growing rapidly. Pakistan is likely facing major energy crisis of natural gas, electricity and oil in the next three to four year that could choke the economic growth. The major shortfall is expected in the natural gas supplies. During the period 1997-98 to 2006-07, average share of natural gas in total energy consumption was 35% and currently its demand is increased to 44%. The demand function of this important source of energy depends on real income per capita and domestic price level. To estimate the natural gas demand equation we begin with a lag structure of order 4 of all three variables included in the gas demand function (i.e. q_t^{gas} , ry_t , p_t) and the model was made parsimonious by reducing the number of lags on the basis of Akaike Information Criteria (AIC) and sequential F -tests for model reduction. Based on AIC and sequential F -tests we select optimal lag length of order 3. To determine the number of cointegration relationships we employ trace test adjusted for the degrees of freedom.⁵ The results are reported in Table 3.

Table 3: Results of Cointegration Tests

Series: (q_t^{gas} , ry_t , p_t) and lags = 3

Engenvalue	Log likelihood	Rank (ρ)	Trace test	p-values
	191.55	0	39.66	0.014**
0.574	205.63	1	19.17	0.069
0.506	217.27	2	2.24	0.729
0.089	218.81	3	-	-

Note: the VAR model includes restricted constant and no trend. We reported trace test adjusted for critical values following Cheung and Lai (1993).

The trace test supports the evidence of one significant cointegrating vector, which implies the existence of a long-run and stable relationship between per capita gas consumption, per capital real income and domestic price level. Normalizing the first cointegrating vector on q_t^{gas} , gives the long-run gas demand function, indicates the presence of positive link with real income per capita and a negative but inelastic elasticity with respect to domestic price level.

⁵ Since our data sample is small. As the sample size is small finite sample adjustment to critical values is warranted (Ahn and Reinsel, 1988; Reimers, 1991 and Cheung and Lai, 1993).

$$q_t^{gas} = 9.62 + 1.05 ry_t - 0.003 p_t \quad (4)$$

s.e (1.46)* (0.47)* (-0.18)

The demand elasticities of natural gas consumption with respect to real income per capita and domestic price level possess expected signs. The coefficient of real income per capita is equal to 1.05 and statistically significant; confirming the role of income in influencing demand for natural gas in the long-run. However, the relative large size of the coefficient indicates that demand for natural gas is elastic with respect to income. The coefficient of price level is negative implies that there is negative relation relationship between gas demand and domestic price level. However, the size of this coefficient is very small and statistically insignificant. This suggests that changes in domestic price level exert almost no impact on gas consumption. These finding indicates that the demand for gas increases as the level of real income increases significantly, while changes in domestic price level produces no impact on natural gas demand in the long-run. This finding implies that gas demand is price inelastic and natural gas is necessity good. These findings are consistent with the earlier findings of Iqbal (1983) and Siddiqui and Haq (1999).⁶

Since all the variables included in the gas demand function are stationary at their first differences. Therefore, we estimate an error-correction model and the results are given by equation (5) and t-statistics are reported in parentheses.

⁶ Iqbal (1983) and Siddiqui and Haq (1999) concluded that in the context of Pakistan the income elasticity of gas demand is higher and price elasticity is lower.

$$\begin{aligned} \Delta q_t^{gas} = & 0.34 + 8.41\Delta q_{t-1}^{gas} + 2.14\Delta q_{t-2}^{gas} - 1.80\Delta q_{t-3}^{gas} - 2.81\Delta ry_{t-2} - 2.25\Delta ry_{t-3} \\ & (4.83)^* \quad (3.96)^* \quad (4.08)^* \quad (-4.05)^* \quad (-3.83)^* \quad (-4.02)^* \\ & - 9.65\Delta p_{t-2} + 3.65\Delta p_{t-3} - 8.64\varepsilon_{t-1}^{gas} \\ & (-4.12)^* \quad (3.88)^* \quad (-3.87)^* \end{aligned}$$

$$\begin{aligned} \text{Log-likelihood} &= 67.83 & \sigma &= 0.03 & \bar{R}^2 &= 0.55 & (5) \\ \text{AR 1-2 test : } F(2,21) & & &= 0.059[0.493] \\ \text{ARCH 1-1 test : } F(1,21) & & &= 0.045[0.834] \\ \text{Normality test : } \chi^2(2) & & &= 5.297[0.071] \\ \text{Hetero test : } F(16,6) & & &= 0.262[0.985] \\ \text{RESET test : } F(1,22) & & &= 0.570[0.458] \end{aligned}$$

The results suggest lagged natural gas consumption, real income per capita and domestic price level are the important determinants of natural gas demand in the short-run. Changes in the past three period's gas consumption exerts positive and negative effect on current gas consumption respectively. The overall impact of past period's gas consumption is positive in the short-run.⁷ The large size of the coefficients of lagged dependent variable suggests the presence of inertia in the adjustment process in the demand for natural gas. The overall impact of real income growth exerts negative impact on gas demand in the short-run. This result suggests that in the short-run consumption of natural gas is luxury rather than necessity good. This result could be possible because natural gas connections are not provided in majority of the rural villages and remote areas; only big cities are connected with gas pipe lines. Thus for rural population, gas is luxury good and for urban population gas may be necessity good. Furthermore, as the income increases population living outside the cities substitutes firewood, kerosene oil and bio-fuel for natural gas. As a consequence, natural gas consumption reduces as the per capita real income increases.

The overall impact of price changes is negative on gas consumption in the short-run. The coefficient of lagged error-correction term has expected negative sign, implying that the deviations of q_t^{gas} from its long-run equilibrium values have the negative feedback effect of restoring equilibrium in the subsequent periods.

⁷ Sum of the short-run elasticities are positive i.e. $8.41+2.14-1.80 = 8.75$

(ii) Electricity demand Function

Electricity is another important source of energy in Pakistan. The average share of electricity in total energy consumption is about 18% during 1997-98 to 2006-07. Electricity consumption grew in all economic sectors during the last five years. Currently Pakistan has facing severe energy crisis, particularly electricity crisis and the electricity shortfall has gone up to 3000 to 4000 MW. This could be due to the mismanagement of electricity demand and supply. For the efficient management of electricity demand and its future needs, the knowledge of demand elasticities is necessary. The accurate estimates of the demand elasticities can be obtained by estimating the electricity demand function.

To estimate electricity demand function we begin with a lag structure of order 4 of per capita electricity consumption (q_t^{elec}), per capita real income (ry_t) and domestic price level (p_t). The model was made parsimonious by reducing the number of lags on the basis of AIC and sequential F -tests for model reduction. Based on AIC and sequential F -tests we select optimal lag length of order 2. To determine the number of cointegration relationship among q_t^{elec} , ry_t and p_t we employ trace test adjusted for degrees of freedom. The results are reported in Table 4.

Table 4: Results of Cointegration Tests
Series: (q_t^{elec} , ry_t , p_t) and lags = 4

Engenvalue	Log likelihood	Rank (ρ)	Trace test	p-values
	214.72	0	28.99	0.202
0.539	227.10	1	13.51	0.332
0.399	235.24	2	3.33	0.531
0.153	237.91	3	-	-

Note: see note below Table 3.

The trace test does not reject the null of no cointegration among the variables included in the electricity demand function. This means that there is no long-run relationship between per capita electricity consumption (q_t^{elec}), per capita real income (ry_t) and domestic price level (p_t).

In the absence of cointegration among the variables we now test the hypothesis of whether the real income per capita and domestic prices play any role in determining the per capita electricity

consumption. For this purpose causality among the per capita electricity consumption, real income per capita and domestic price level and the most parsimonious results are represented by equation (6).

$$\Delta q_t^{elec} = 0.74\Delta q_{t-2}^{elec} + 0.31\Delta q_{t-3}^{elec} + 0.35\Delta r y_{t-1} - 0.66\Delta p_{t-2} + 0.42\Delta p_{t-4}$$

(5.43)* (2.40)** (2.64)** (-3.98)* (3.84)*

$$R^2 = 0.82 \quad \sigma = 0.03 \quad RSS = 0.02$$

<i>AR</i> 1–2 test : $F(2, 24)$	= 0.355[0.705]	(6)
<i>ARCH</i> 1–1 test : $F(1, 24)$	= 0.272[0.607]	
<i>Normality</i> test : $\chi^2(2)$	= 0.034[0.983]	
<i>Hetero</i> test : $F(10, 15)$	= 1.569[0.209]	
<i>Hetero – X</i> test : $F(20, 5)$	= 1.174[0.470]	
<i>RESET</i> test : $F(1, 25)$	= 0.512[0.481]	

The results presented in equation (6) suggest that the demand for electricity is significantly determined by the lagged electricity demand, lagged real income growth and lagged domestic price changes in the short-run. The electricity consumption lagged by two and three year exerts positive impact on the current electricity consumption. Similarly, the growth of real income per capita influences current electricity consumption growth positively. However, changes in real income per capita take one year to produce changes in current electricity consumption per capita. The effect of domestic price changes on current electricity demand lagged by two and four years remains negative and positive and significant respectively. However, the overall impact of price changes remains negative in the short-run. The short-run electricity demand function passes all the diagnostic tests.

We also employ VAR Granger causality/Block exogeneity Wald tests and the results suggest that both real income per capita and domestic price level causes electricity demand in the short-run. However, neither per capita electricity consumption and domestic price level causes real GDP per capita nor per capita electricity consumption and real GDP per capita causes domestic price

level in the short-run. This result suggests that income and pricing policies play an important role in the determination of electricity consumption.

(iii) Coal Demand function

Coal is mainly used in power, brick-kilns and cement industries. In 2006-07, the share of coal in overall energy mix is 7.5 per cent only. During 2007-08, about 53 percent of total coal production is being utilized by brick-kilns industries and 44.6 per cent coal is consuming by cement industry, while power sector consuming only 2.2 per cent. About 80 per cent of cement industries has switched over to coal from furnace oil due to high furnace prices. This has generated the demand for coal around 2.5 to 3.0 million tones per annum (GOP, 2007-08). The consumption of coal is related to GDP and coal is used in industries that contribute to economic growth. Therefore, an econometric model is required to determine the impact of GDP and domestic price level on the consumption of coal.

To examine the coal demand, we start with 4 lags and tested down sequentially. The optimal lag length of order 2 is chosen on the basis of AIC and sequential F -statistic. To determine the cointegration between per capita coal consumption, per capita real GDP and domestic price level, we employ trace test adjusted for degrees of freedom following Cheung and Lai (1993) procedure. Table 5 reports the cointegration results for per capita coal consumption.

Table 5: Results of Cointegration Tests
Series: (q_t^{coal}, ry_t, p_t) and lags = 2

Engenvalue	Log likelihood	Rank (ρ)	Trace test	p-values
	168.86	0	33.72	0.070
0.517	181.24	1	13.32	0.346
0.261	186.37	2	4.84	0.309
0.160	189.33	3	-	-

Note: See note below Table 3.

It can be seen from the Table 8 that the trace test does not reject the null of no cointegration between per capita coal consumption (q_t^{coal}), real GDP per capita (ry_t) and domestic price level (p_t). This result implies that there is no long-run relationship between the variables included in the coal demand function.

In the absence of cointegration among the variables we now test the hypothesis of whether the real income per capita and domestic prices play any role in determining the per capita coal consumption. To this end, causality between the per capita coal consumption, real income per capita and domestic price level is examined and the most parsimonious results are represented by equation (7).

$$\Delta q_t^{coal} = -0.55\Delta q_{t-1}^{coal} + 0.96\Delta ry_{t-1} + 1.10\Delta ry_{t-2} + 1.28\Delta p_t - 1.40\Delta p_{t-2}$$

$$\begin{matrix} (-3.72)^* & (2.67)^{**} & (2.83)^{**} & (3.12)^* & (-4.01)^* \end{matrix}$$

$$R^2 = 0.56 \quad \sigma = 0.08 \quad RSS = 0.19$$

$$\begin{matrix} AR\ 1-2\ test : F(2,26) & = & 0.166[0.848] \\ ARCH\ 1-1\ test : F(1,26) & = & 0.039[0.845] \\ Noprmlality\ test : \chi^2(2) & = & 0.687[0.709] \\ Hetero\ test : F(10,17) & = & 0.992[0.486] \\ Hetero - X\ test : F(20,7) & = & 0.820[0.662] \\ RESET\ test : F(1,27) & = & 0.008[0.931] \end{matrix} \quad (7)$$

The results reported in equation (7) suggest that coal demand is significantly determined by real income and domestic price level significantly in the short-run. The sum of the short-run elasticities of coal demand with respect to real income is positive and greater than unity. However, the impact of real income per capita passes on coal consumption after one and two years. This finding suggest that coal demand is income elastic which means that when income increases the demand for coal is also increases but more than proportionately. Similarly, the sum of short-run elasticities with respect to domestic price level is negative and very small (i.e. 1.28-1.40 = -0.12). This implies that the demand for coal is price inelastic for industries consuming coal in the short-run. The estimated equation passes all the diagnostic tests and there is no econometric problem.

To examine the causality we employ VAR Granger causality/ block exogeneity Wald test. The result suggests that both real income and domestic price level causes coal demand significantly in the short-run. However, no VAR causality has been observed from coal consumption and

domestic price level to real GDP or from coal consumption and real GDP to domestic price level in the short-run. This result implies that income and pricing policies play very important role in the determination of coal demand.

5. Conclusions

In this study we analyzed the energy demand at disaggregate level using annual data covering the period 1972 to 2007. We find long-run relationship only in the case of gas demand. The results of the gas demand equation suggest that in the long-run only real income per capital exerts positive impact on gas consumption, while domestic price play no role at all to influence the gas demand in the long-run. However, in the short-run average impact of real income per capita and domestic price remains positive and negative significantly. The error-correction term is negative and significant supporting the evidence of long-run causality between gas consumption, real income and domestic price level.

No evidence of cointegration observed for the case of electricity and coal demand functions. Therefore, we have estimated short-run dynamic demand functions for electricity and coal. In both cases the overall impact of real income and domestic price level remains positive and negative respectively. The average income elasticity of gas and coal is higher than that of electricity (in absolute terms). The average price elasticity of gas consumption is much higher than that of electricity and coal consumption (in absolute terms). The differences in the price elasticities for each component of energy have clear implications for taxation and income generation. In the short-run the average price and income elasticities of electricity and coal (in absolute terms) are small than that of gas with may indicate that in Pakistan electricity and coal is consider as necessity good. These findings are very important for income and pricing policies. To design appropriate energy pricing policy, up to date estimates of price and income elasticities of gas, electricity and coal demand that this study provides, will prove useful. The policymakers and private investors could be benefit from this study because it provides useful information regarding the market for energy demand.

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