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Dynamics of Energy Consumption, Technological Innovations and Economic Growth in Pakistan

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Abstract

The objective of this study is to investigate the impact of technological innovations (TI henceforth) on energy use at aggregate and disaggregate levels for the economy of Pakistan. Using an extended Marshallian demand function this study fails to confirm the negative relationship between TI and energy use over the period 1971-2013 through autoregressive distributed lag (ARDL) bound testing approach. This might be due to the reason that the introduction and adoption of new and efficient technologies has created further energy demand in the system through broadening of the consumer base. At the disaggregated level, while TI has put an upward pressure on natural gas and coal consumption, nonetheless, it has significantly improved efficiency in the oil sector, thereby reducing oil demand in the long-run. It has also been found that energy demand is price and income inelastic in the long-run. However, an increase in per capita GDP is positively associated with energy demand in the short-run. Improvement in country's competitiveness captured through trade openness, has proven to be one of the important determinant of energy demand in the long-run.

Key words: Energy consumption, technological innovations, trade openness, economic growth, Pakistan.

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1. Introduction

The accelerating economic growth in emerging economies has put increasing pressure on world commodity markets, especially energy demand. Since the enhanced energy demand is being met through combustion of non-renewable fossil fuels like crude oil, natural gas and coal, consequently, the greenhouse gas emissions has grown rapidly during the last two decades. According to the Intergovernmental Panel on Climate Change (IPCC) the world climate has significantly changed due to human activities. Although the establishment of United Nations Convention on Climate Change (UNFCCC) and the adoption of COP 21 recommendations in Paris are designed to reduce the adverse impact of environmental degradation on world economic growth, ensuring sustainable and emission free environment, appears to be a distant dream at the moment.

The objective of the present study is to understand the dynamics of energy-economy nexus for Pakistan as it is believed that there is a strong link between degree of economic activity and energy consumption. Like other developing countries, Pakistan's economy has undergone the process of structural transformation, whereby, the relative share of different sectors in GDP has changed significantly. From a time when agriculture was the mainstay of the economy with a whopping share of 60 percent in GDP, its share has now reduced to about 20 percent (Pakistan Economic Survey, 2015). The space created by agriculture has been taken over by energy intensive industrial and services sectors. This change, as a result, has created huge energy demand in the country[1]. Since Pakistan is a net energy importing country, this sectoral shift has put huge stress on meager foreign exchange resources available with the Government. Within this context it is important to understand how future energy demand will shape up and how technological innovations and international competitiveness will affect the future consumer base. It is argued in this study that trade openness is one of the important factors that stimulate energy demand through economies of

[1] Pakistan's total energy consumption has increased from 0.63 to 2.64 quadrillion BTU (British thermal unit) between 1980 and 2012 (US Energy Information Administration).

scale, economies of scope, diversification, specialization and access to improved technology. It causes changes in the relative shares of factors of production through specialization as the economies open up. Similarly, international trade through economies of scale help in reducing average cost of production and promote competitiveness of the domestic firms that ultimately leads to improvement in energy efficiency. Finally, trade openness enables domestic firms to use efficient technologies that enable them to reduce the energy demand. However, it is also possible that reduced cost of energy may encourage others to expand its consumption. TI is another important factor that affects energy demand. Whereas the adoption of improved technologies promotes efficiency through technological diffusion, it also compensates the high energy demand up to some extent (Yanikkaya, 2003 & Wan et al., 2015). However, the recent literature focuses the role of technological advancement on energy-growth nexus through the existence or absence of rebound effect which suggests that technological improvement enhances efficiency and reduces the cost of production that, in turn, encourages energy demand.

The augmented demand function is being estimated in the present study to derive short and long-run price and income elasticities. The probable role of technological innovations and competitiveness on energy use is also examined by extending the model specification. The time series data used in this study ranges between 1971 and 2013. The study is arranged as follows. The section after introduction reviews the existing relevant literature. Section 3 provides the detailed discussion on variables, data and methods employed for analysis. Section 4 reports the estimated results, and the final section 5 concludes the analysis and offers policy recommendations.

2. Literature Review

The causal relationship between energy use and economic activities is well established in energy economics literature. The pioneering contribution of Kraft and Kraft (1978) has opened up new vistas to study the energy-economy nexus. The literature is well diversified in terms of regions and countries, application of econometric methods, and the use of proxy variables for energy consumption and economic activity. The outcome of these studies is varied and sometimes conflicting in nature. The variations range from direction of causality to the magnitude of impact between the variables of interest. As the policy implications mainly depend on these results, hence inaccurate and inconsistent results often lead to inappropriate policy prescriptions which at times are in conflict with the economic health of economies.

Based on the existing literature, the major findings can be classified into four categories on the basis of their policy implications. The first strand of literature reports no causality between energy use and economic growth and generally termed as 'neutrality hypothesis, in the energy economics literature. It implies that any kind of energy policy will have no adverse consequences for economic growth. Payne (2009) and Menegaki (2011) are the latest references in this regard. The second strand of literature finds unidirectional causality running from economic growth to energy consumption and it is referred to as the 'conservation hypothesis'. It means that the surge in economic activity puts extra pressure on energy demand which suggests that energy conservation and efficiency enhancing policies can be implemented without harming economic growth. Kraft and Kraft (1978), Sari et al., (2008), Eden and Jin (1992) for the US economy, Cheng and Lai (1997) for Taiwan, Aqeel and Butt (2001) for Pakistan, Fatai et al., (2002) for New Zealand, Jobert and Karanfil (2007) for Turkey, Zamani (2007) for Iran, Ang (2008) for Malysia have found support of the conservation hypothesis using a variety of econometric techniques. The third strand of literature relates to 'growth hypothesis' which says the causality runs from energy consumption to economic growth. In terms of policy perspective, this result shows that energy is an important ingredient to economic growth and the energy curtailing policies may pose an adverse impact on growth. Stern (1993, 2000) for the US, Soytas et al. (2001) for Turkey and Belloumi (2009) for Tunisia have reported uni-directional causality running from energy consumption to economic growth. The fourth strand of literature relates to the 'feedback hypothesis' which confirms bi-directional causality between economic growth and energy consumption. These studies demonstrate that energy and growth are interdependent and jointly determined. Hwang and Gum (1992) for Taiwan, Glasure (2002) for Korea, Hondroyiannis et al. (2002), Ghali and El-Sakka (2004) for Canada, Paul and Bhattacharya (2004) for India and Erdal et al. (2008) for Turkey which reported bi-directional causality.

Based on the nature of relationship, several studies have examined the role of energy product prices on energy consumption. Most of these studies have failed to find significant impact of price variation on energy demand which means that energy demand is price inelastic. For instance, Zhou and Teng (2013) estimated the price elasticity of energy demand for China and found insignificant price elasticity. Similarly, Dhal (2012) using a panel of 120 countries, and Altinay (2007) using data from Turkey have concluded that energy, with no close alternative is an essential and price inelastic commodity.

Some recent studies have investigated the role of trade openness and TI on energy demand. Sadorsky (2011), and Shahbaz et al., (2014) have documented that energy demand and trade volumes have inverted U shaped relationship in low and middle income countries. On the other hand, Yanikkaya (2003) and Wan et al., (2015) have argued that trade openness promotes efficiency through technological diffusion thus compensates the high energy demand up to some extent. Recent literature focuses the role of technological advancement on energy-growth nexus through the existence or absence of rebound effect which suggests that technological improvement enhances efficiency and reduces the cost of production thus encouraging energy demand.

In case of Pakistan, several studies have focused on the direction of causality and others have investigated the energy-economy nexus through various econometric techniques at aggregate and disaggregate levels[2]. On aggregate level Hye and Riaz (2008), Kumar and Shehbaz (2012) found bi-

[2] See for example, Siddiqui (1999) and Muhammad (2000)

directional causality between energy consumption and economic growth for Pakistan. However, Khan and Qayyum (2009) reported unidirectional causality from energy demand to economic growth. Noor and Siddiqui (2010) reported that economic growth has stimulated energy consumption for SAARC countries. On the disaggregated level Aqeel and Butt (2001) is one of the preliminary studies which examined the direction of causality between economic growth and various energy sources using Hsiao's Granger causality test. They found uni-directional causality running from economic growth to oil and electricity use to economic growth but ruled out any causality between economic growth and natural gas consumption. Siddique (2004) validated the Aqeel and Butt (2001) findings. Khan and Ahmed (2008) is another important study regarding disaggregated analysis of energy-economy nexus.

Additionally, Shahbaz et al (2013), Shahbaz et al. (2014), Shahbaz et al., (2012), Shahbaz and Lean (2012), and Shehbaz and Feridun (2012) are the worth noting studies that have attempted to explore the causal relationship and long-run association between electricity consumption, natural gas consumption and economic growth for Pakistan employing ARDL bound testing approach and Granger causality test. On methodological grounds Shahbaz et al. (2014) is followed in this study. However, they studied the demand for natural gas only by contextualizing the energy sector reforms and the possible role of structural break, whereas the present study covers all major energy sources and it also extends the scope by incorporating the role of TI and trade openness in the model that has not been examined previously.

3. Model Specification, Data and Methodology

This study uses an augmented Marshallian demand function to examine the role of different factors affecting the demand for various energy products assuming market clearing conditions. Based on theory, the consumption demand for final energy (any product) at time t can be expressed as:

$$EC_t = f(Y_t, P_{et}) \qquad (1)$$

Where EC_t= energy consumption at time t, Y_t = income level at time t and P_{et} = energy price at time t.

The specification of this model is extended by incorporating trade openness and TI as additional variables that affect energy demand in an open economy. The revised consumption function can be written as:

$$EC_t = f\,(Y_t,\, P_{et},\, TI_t,\, TO_t) \qquad (2)$$

Where $TI_{t\,=}$ Technological innovations at time t; and TO is trade openness at time t. The expected signs of the coefficients for different variables (elasticity of demand w.r.t. the corresponding variables are as follows:

$$\frac{\partial E_t / \partial y_t}{E_t / y_t} = \xi_{ye} > 0, \qquad \frac{\partial E_t / \partial pe_t}{E_t / pe_t} = \xi_{pe} < 0, \qquad \frac{\partial E_t / \partial ti_t}{E_t / ti_t} = \xi_{tie} \gtreqless 0,$$

$$\frac{\partial E_t / \partial to_t}{E_t / to_t} = \xi_{toe} \gtreqless 0$$

Where ξ represents energy elasticity of demand with respect to each independent variable. The sign for income elasticity of demand ξ_{ye} is expected to be positive implies an increase in real income stimulates energy demand. Price elasticity of demand ξ_{pe} should be negative as price increase erodes purchasing power of the economic agents. The elasticity of energy demand with respect to trade openness ξ_{toe} depends on the relative impact of trade openness on economic activity and the transference of modern and energy efficient technology from more advanced trading partners. Similarly, the elasticity of energy demand with respect to TI may be positive or negative depending on the nature of innovation to technology, and its relative impact on production and consumption. The estimable energy demand function (on aggregate and disaggregate levels) is specified as:

$$EC_{i,t} = \theta_0 + \theta_1 YPC_t + \theta_2 P_t + \theta_3 TO_t + \theta_4 TI_t + \varepsilon_t \quad (3)$$

Where $EC_{i,t}$ denotes logarithmic form of per capita final energy consumption of various type given that "i" stands for per capita consumption of total, natural gas, petroleum products, electricity and coal. YPC_t indicates per capita real GDP, P_t is the energy price, TO_t is trade openness and finally, TI_t stand for technological innovation introduced in the country at time t.

3.1 Methodology

This paper opts for ARDL bound testing approach developed by Pesaran et al. (2001) to examine the role of various factors on energy demand. There are many reasons for the selection of this technique. For example, this method enables us to estimate short-run and long-run elasticities simultaneously. Secondly, this test out-performs in small samples as compared to other tests. Thirdly, this test remains statistically significant whether the order of integration is I(0) or I(1). Compared to this, the other methods such as the Granger causality test and the Johansen test of cointegration have certain drawbacks that are well specified in the literature.[3] Before estimation of the core model, the optimal lag length is selected through Schwarz information criterion and the ARDL version of (VECM) model is specified as below:

$$\Delta ECT_t = \alpha_0 + \gamma_1 ECT_{t-1} + \gamma_2 YPC_{t-1} + \gamma_3 P_{t-1} + \gamma_4 TI_{t-1} + \gamma_5 TO_{t-1} + \sum_{i=1}^{p} \eta_i \Delta ECT_{t-i} + \sum_{j=1}^{q} \eta_j \Delta YPC_{t-j} + \sum_{k=1}^{q} \eta_k \Delta P_{t-k} + \sum_{l=1}^{q} \eta_l \Delta TI_{t-l} + \sum_{m=1}^{q} \eta_m \Delta TO_{t-m} + \varepsilon_t \quad (4)$$

Where Δ is the first difference operator, α_0, is the constant term, ECT_{t-1}, YPC_{t-1}, P_{t-1} and TO_{t-1} are the one year lagged values of the variables already defined. γ_1, γ_2, γ_3, γ_4 and γ_5 are the long run coefficients indicating long-run elasticities of energy demand. $\sum_{i=1}^{p} \eta_i \Delta EC_{t-i}$ indicates summation of the

[3] See Greene (2003) and Enders (2008).

coefficients for dependent variable with optimal lag length from 1 to p and for independent variables it can be from 1 to q. ε_t is the white noise error term.

3.2 Estimation Procedure

The estimation procedure initiates with estimating the unrestricted error correction model specified in equation 4 and $(p + 1)^k$ regressions are estimated for each equation. To determine the long-run relationship between variables of interest, the estimation is carried out through OLS. The Wald coefficient restriction test based on F-statistic is conducted to check for the overall significance of the coefficients of the lagged variables. The F-statistic tests the null hypothesis: (H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0$) assuming no cointegration relationship against the alternative hypothesis (H_a: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq 0$) implies existence of cointegrating relationship. Finally, the calculated value of F-statistic is compared with critical values (bounds) provided by Pesaran et al. (2001). If the calculated value is larger than the upper bound the null hypothesis of no cointegration is rejected and the existence of long-run relationship is accepted. On the other hand, when the calculated value is comparatively smaller than the lower bound, the null hypothesis of no cointegration is accepted. In such case where the calculated F-statistic lies between the bounds (upper and lower critical values), the test stand to be inconclusive.

The final step of the methodology is the error correction modeling (equation. 5) to gauge the short-run dynamics. Here the error correction term shows the speed of adjustment towards long-run equilibrium.

$$\Delta ECT_t = \alpha_0 + \sum_{i=1}^{p} \eta_i \Delta ECT_{t-i} + \sum_{j=1}^{q} \eta_j \Delta YPC_{t-j} + \sum_{k=1}^{q} \eta_k \Delta P_{t-k} + \sum_{l=1}^{q} \eta_l \Delta TI_{t-l} + \sum_{m=1}^{q} \eta_m \Delta TO_{t-m} + \omega\, ect_{t-1} + \varepsilon_t \quad (5)$$

A battery of tests is also employed to ensure the statistical adequacy of the model. Cumulative sum of recursive residuals and Cumulative sum of squared recursive residuals tests have been employed to examine the stability of the coefficients. Moreover, to avoid the problems of serial correlation, heteroscedasticity and misspecification have been confirmed through ARCH test, LM test and Ramsey Reset test are employed and finally, the goodness of fit and normality of residuals are also dealt with carefully.

3.3 Data Sources and Variables

The estimation of the model is based on annual data covering the period 1971-2013 with total of 43 observations. Data on final energy consumption at disaggregated level is taken from Pakistan Economic Survey (various issues). Per capita consumption of natural gas (mmcft , excluding LPG), oil/petroleum products (tons), coal (000 metric ton) and electricity (Gwh) consumption is obtained through dividing consumption of each component by total population.[4] The data on per capita aggregate energy consumption (energy use in kg of oil equivalent per capita), GDP per capita, GDP, Consumer Price Index CPI (2010 as base), population, exports, imports and number of patent applications are retrieved from World Bank database, the World Development Indicators website. The ratio of exports and imports to GDP is used as proxy for trade openness. Like many other studies, including Ang (2009), Schmoch (2007), and Tang (2013), total number of patent applications filed in a year is taken as proxy for TI. These are the applications filed by (residents and nonresidents) with National Patent Office, Pakistan for exclusive rights for an innovation (product or process)[5] that provides a new solution (technical) to a problem for a limited period of time.

Due to non-availability of energy price data (aggregate and various components), authors have relied on CPI as proxy for energy prices at

[4] The most recent data on energy consumption is obtained from Pakistan Energy Yearbook (2014).

[5] Process may be defined as "any art, process or method or manner of new manufacture of product and product means any substance, article, apparatus or machine. Data on process and product in our study have been taken from World Development Indicators (WDI) database.

aggregate and disaggregate level as has also been done by Galindo, (2005), Akinlo (2008) and Khan and Ahmed (2008). This may be a better choice of variables as the observed energy prices of various products are distorted as they include large subsidies.

4. Results and Discussion

4.1 Unit root and Stationarity of the Respective Variables

Prior to estimation, it is important to determine the statistical adequacy of the underlying methodology for deriving robust policy implications. This study makes use of ARDL approach to examine the short-run and long-run relationship between energy consumption and other variables of interest. However, the appropriateness of the ARDL approach depends on the order of integration and require the variables to be either I(0), I(1) or mix of I(0) and I(1). Considering the problems of size and power associated with conventional unit root test, authors resorted to tests which are appropriate in our case. For this purpose Ng-Perron (2001) test is used along with Zivot-Andrews (1992) structural break unit root test to check the order of integration of the respective variables. Ng-Perron test is the modified version of Philips-Perron (1988) unit root test. This modification has up tosome extent, resolved the issues of size and power involved with other conventional tests. The Ng-Perron's four test statistics are based on Philip-Perron Z_α, Z_t, Bhargava (1986) R_1 statistics and the critical values provided by Elliot et al. (1996). The standard notations[6] used for the test statistics of the GLS de-trended data y_T^d can be written as,

$$k = \sum_{t=2}^{T}(y_{t-1}^d)^2/T^2 \tag{6}$$

$$MZA = (T^{-1}(y_T^d)^2 - f_0)/(2k) \tag{7}$$

$$MZT = M\,Z_\alpha \times MSB \tag{8}$$

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[6] For details see Ng-Perron (2001).

$$MSB = \left(\frac{k}{f_0}\right)^{1/2} \tag{9}$$

$$MPT = \frac{\bar{\varepsilon}^2 k - \bar{\varepsilon} T^{-1}\left(y_T^d\right)^2}{f_0} \quad if\ x_t = \{1\} \text{ and}$$

$$MPT = \frac{\bar{\varepsilon}^2 k + (1-\bar{\varepsilon}) T^{-1}\left(y_T^d\right)^2}{f_0} \quad if\ x_t = \{1, t\} \tag{10}$$

Keeping in view the structural reforms initiated at different points of time during the period of analysis alternative methodology is needed that endogenize the break date. In this regard various methodologies have been adopted. Zivot-Andrews developed one such methodology test which focuses on time structural break.

$$\Delta y_t = \tau + \partial y_{t-1} + \beta t + \delta \mathfrak{D}\mathrm{U}_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \tag{11}$$

$$\Delta y_t = \tau + \partial y_{t-1} + \beta t + \partial \mathfrak{D}\mathrm{T}_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \tag{12}$$

$$\Delta y_t = \tau + \partial y_{t-1} + \beta t + \delta \mathfrak{D}\mathrm{U}_t + \partial \mathfrak{D}\mathrm{T}_t + \sum_{j=1}^{k} d_j \Delta y_{t-j} + \varepsilon_t \tag{13}$$

Where the $\mathfrak{D}\mathrm{U}_t$ is a dummy variable indicating mean shift occurred with time break TB and $\mathfrak{D}\mathrm{T}_t$ indicates trend shift. Thus, equation (11) and (12) consider one-time shift at level and trend respectively and equation (13) implies one-time change both in level and trend simultaneously.

$$\mathfrak{D}\mathrm{U}_t = 1 \quad if\ t > TB\ and\ \mathfrak{D}\mathrm{U}_t = 0\ if\ t \le TB \quad \text{and}$$

$$\mathfrak{D}\mathrm{T}_t = t - TB \quad if\ t > TB \quad and\ \mathfrak{D}\mathrm{T}_t = 0 \quad if\ t \le TB$$

The null hypothesis of $\partial = 0$ is assumed in all the three equations

Table 1

Ng-Perron Unit Root Test

	Test-Statistics at Level				Test Statistics at First Difference			
	MZA	MZT	MSB	MPT	MZA	MZT	MSB	MPT
Real GDP per capita	-6.02	-1.70	0.28	15.10	-17.67	-2.97	0.17	5.16
Technological Innovations	-5.71	-1.67	0.29	15.92	-16.54	-2.87	0.17	5.52
Trade Openness	-8.76	-2.08	0.24	10.44	-16.76	-2.89	0.17	5.47
Energy Consumption								
Aggregate	-1.61	-0.47	0.29	25.85	-19.39	-3.02	0.16	5.27
Natural Gas	-14.09	-2.49	0.18	7.38	-18.26	-3.02	0.17	5.03
Petroleum Products	-2.19	-0.95	0.43	36.62	-11.65	-2.38	0.20	7.99
Electricity	-4.67	-1.38	0.30	18.53	-17.67	-2.96	0.17	5.23
Coal	-8.11	-1.91	0.23	11.54	-20.01	-3.16	0.16	4.56
Energy Price	-13.14	-2.56	0.19	6.95	-6.90	-1.85	0.27	13.22
Significance level	MZA	MZT	MSB	MPT				
0.01	-23.8	-3.42	0.143	4.03				
0.05	-17.3	-2.91	0.168	5.48				
0.10	-14.2	-2.62	0.185	6.67				

Note: MZA and MZT are the modified versions of Philip-Perron ZA and ZT. For precise definitions of MZA, MZT, MSB and MPT are given in equations 6-10.

Table 2
Zivot-Andrews Structural Break Unit Root Test

	Test-Statistics at Level			Test Statistics at First Difference		
Variable	t-statistic	p-value	Break date	t-statistic	p-value	Break date
Real GDP per Capita	-3.16	0.85	1996	-6.06	< 0.01	1992
Technological Innovations	-3.83	0.47	2009	-6.49	< 0.01	2006
Trade Openness	-5.84	< 0.01	2002	-6.98	< 0.01	1992
Energy Consumption						
Aggregate	-2.04	0.99	2007	-7.004	< 0.01	2007
Natural Gas	-3.94	0.4	2010	-9.19	< 0.01	1989
Petroleum Products	-3.91	0.43	2001	-8.41	< 0.01	2003
Electricity	-3.71	0.56	2007	-11.6	< 0.01	2009
Coal	-4.65	0.08	2007	-7.97	< 0.01	1999
Energy Price	-6.205	< 0.01	2010	-5.27	< 0.01	2007

(equations 11-13) which implies the existence of unit root problem excluding any structural change. The alternative hypothesis of $\partial < 0$ implies trend stationarity with one time break (TB) at some unknown point.

The Ng-Perron test results are reported in Table 1, showing that all variables are non-stationary at level and become stationary at first difference. These results confirm that all series are integrated of order one I(1) with intercept and trend. On the other hand, internalizing the shifting structure of the economy and energy mix due to structural reforms introduced in 1990s Zivot-Andrew structural break test is used. Assuming structural breaks the Zivot-Andrews test results reported in Table 2 indicate that trade openness and price level series are I(0) while other variables are I(1). Therefore, results support the appropriateness of ARDL approach hence the study proceeds with the estimation of basic model specified in equation (4).

4.2 Cointegration Analysis and Long-run Relationship

Keeping in view the mixed order of integration I(0) and I(1) of the corresponding variables the ARDL bound testing approach to cointegration proposed by Pesaran et. al., (2001) is used. The estimation of equation 4 involves selection of optimal lag length which is critical and needs to be carefully identified. Accordingly Schwarz criterion is used and the optimal lag length selected in each case is reported in column 4 of Table 3.

ARDL bound test approach is based on Wald coefficient test that examines the joint significance of the coefficients of lagged variables with the null hypothesis $(\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = 0)$ 0f no long-run relationship. In case, the null hypothesis of no cointegration is rejected the alternative of cointegration or inconclusiveness is considered on the basis of comparison between F-statistic (calculated) and critical values provided by Pesaran et. al., (2001). This study calculates five F-statistics one for aggregate energy consumption and four for disaggregated energy consumption functions.

The results obtained through ARDL bound testing approach are also reported in Table 3, show that the calculated F-statistic for total energy

Table 3
ARDL Bounds Test Approach Results

Dependent Variable	Independent Variable	F-statistic	Optimal Lag-Length	Result
Aggregate Energy Consumption	YPC, P, TO TI	7.470555	(4, 4, 4, 2, 4)	Cointegration
Petroleum Products	YPC, P, TO TI	6.135497	(1, 0, 0, 4, 0)	Cointegration
Natural Gas	YPC, P, TO TI	3.157236	(1, 1, 2, 1, 0)	Inconclusive
Electricity	YPC, P, TO TI	5.087532	(4, 1, 4, 4, 3)	Cointegration
Coal	YPC, P, TO TI	3.922656	(2, 0, 2, 0, 3)	Cointegration
Real GDP per capita	ECT, P, TO TI	4.138751	(4, 4, 2, 4, 4)	Cointegration
	ECO, P, TO TI	2.684455	(2, 4, 2, 1, 4)	No Cointegration
	ECNG, P, TO TI	4.007711	(1, 0, 1, 0, 4)	Cointegration
	ECEL, P, TO TI	1.180241	(1, 3, 2, 1, 4)	No Cointegration
	ECC, P, TO TI	5.592409	(1, 3, 0, 3, 1)	Cointegration
Critical Value Bounds				
Significance level	I0 Bound	I1 Bound		
10%	2.45	3.52		
5%	2.86	4.01		
1%	3.74	5.06		

consumption, petroleum products consumption, natural gas consumption, electricity consumption and coal consumption are 7.47, 6.13, 3.16, 5.08 and 3.92, respectively. The comparative analysis of F-statistics reported in Table 3(column 3) indicates that the calculated F-values for total energy, petroleum products, electricity and coal consumption are larger than the critical value (upper bound) at the 5 percent level of significance. Thus, the null hypothesis of no cointegration is rejected and the alternative hypothesis of the existence of long-run relationship is accepted. In case of natural gas consumption the test is inconclusive as the calculated F-statistic value falls between the bounds. The overall analysis confirms the existence of cointegration between various energy demand functions (aggregate, petroleum products, electricity and coal), trade openness, TI, energy price and real GDP per capita. However, there is not enough evidence to reject or accept the existence of cointegration for natural gas consumption in Pakistan. The second portion of Table 3 reports the results of the cointegration where real GDP per capita is taken as dependent variable and energy variables along with trade openness and TI are considered as independent variables. It is evident that cointegration exists between real GDP per capita and aggregate energy consumption, natural gas and coal. On the other hand, in case of electricity and petroleum products, cointegration does not exist. On the whole, the results indicate that GDP per capita depends on aggregate energy consumption, natural gas and coal. Thus there is bi-directional relationship between aggregate energy consumption and coal consumption with real GDP per capita, whereas in case of other components uni-directional relationship has been found.

4.3 Impact of Technological Innovation Over the Long-Run

After establishing cointegration relationship between energy demand (at aggregate and disaggregate levels) and other variables, the long-run elasticities of the respective variables in equation 5 are calcuated. Taking the lag length specification already decided (Column 4 of Table 3) estimated equation 5 is estimated. Interestingly, in case of total energy demand function, the trade openness coefficient is negative and significant at 5 percent significance level. Another important finding is that the coefficient for TI is also significant at 10 percent significance level but with positive sign. However, elasticity of energy demand with respect to real GDP per capita and energy price are insignificant implying income and price variations doesn't affect energy consumption in the long-run.

The negative coefficient for TI in oil demand function demonstrates that demand for petroleum products is negatively associated with TI. However, no other variable cause any significant impact on the demand for petroleum products. Natural gas consumption also mainly depends on TI with positive sign implying that innovations have a role in its demand. Compared to this GDP per capita, trade openness and price level seem to plays no important role in natural gas consumption in Pakistan. Electricity consumption shows the similar pattern as was observed for petroleum products. The only significant coefficient is technological innovation, but hence it appears with a

Table 4
Long-run Coefficients

	Aggregate		Petroleum Products		Natural gas		Electricity		Coal	
Variable	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.	Coefficient	Prob.
Real GDP per Capita	-0.10	0.65	0.85	0.22	0.54	0.32	0.19	0.85	3.48*	0.00
Energy Price	0.19	0.11	0.23	0.29	0.21	0.17	0.30	0.29	-0.79*	0.00
Technological Innovations	0.06*	0.00	-0.56*	0.00	0.18***	0.07	-0.40	0.17	0.56*	0.00
Trade Openness	-0.31**	0.02	-0.34	0.28	0.43	0.11	-1.90**	0.02	0.71*	0.00
Constant Term	2.87*	0.00	0.45	0.79	-2.26	0.11	3.77	0.31	-9.53*	0.00

Note: *, **, ***indicates significance at 1%, 5% and 10% critical values.

negative sign it means that TI has enhanced efficiency in electricity consumption. In case of coal consumption the coefficient of TI along with trade openness and GDP per capita are positive and highly significant at1 percent level.

Looking at Table 4 horizontally, it can be seen that TI is the most important factor determining the energy consumption at different levels. Trade openness is the second important variable while GDP per capita and price level are the least important factors affecting energy consumption in the economy in the long-run.

4.4 Short-Run Elasticities of Energy Demand

The short-run elasticities of energy demand are calculated along with error correction term and reported in Table 5. The estimated results indicate that demand for various energy products are mainly driven by real GDP per capita in the short-run. The coefficient of GDP per capita is positive and significant for natural gas, coal and electricity consumption, however insignificant for petroleum products. The most promising result is associated with the coefficient of technological innovation in most of the cases it is positive and statistically significant except for natural gas. It shows that the introduction of new technologies in the country has widened the consumer base and as a result the demand for various energy products has gone up. It could also be the case that modern technologies introduced in Pakistan are energy intensive rather than energy efficient. The coefficient of price level is insignificant for petroleum products and natural gas, however for coal and electricity it is significant and negatively associated with electricity and coal use. These findings show that the demand for petroleum products and natural gas is price inelastic. Trade openness has no impact on oil related products and natural gas demand but has significant positive impact on electricity and coal use.

Finally, the error correction term suggests convergence of short-run deviations towards the long-run equilibrium with different speeds of

Table 5
Short-run Coefficients

	Petroleum Products		Natural gas		Coal		Electricity	
	Coef.	t-Statistic	Coef.	t-Statistic	Coef.	t-Statistic	Coef.	t-Statistic
D(YPC)	0.23	1.29	2.16**	1.97	2.45*	5.10	1.40**	2.26
D(P(-1))			-0.36	-0.80	-1.15**	-2.26	-2.66*	-3.99
D(P(-2))							1.87*	2.90
D(P(-3))							-0.66*	-2.21
D(TI(-1))	0.23**	1.99			0.30	1.38	0.10	0.64
D(TI(-2))	-0.04	-0.33			-0.60*	-4.00	0.25***	1.77
D(TI(-3))	0.14***	1.81					-0.14	-1.25
D(TO(-1))							-0.08	-0.52
D(TO(-2))							0.41*	2.72
D(EEL(-1))							-0.41**	-2.48
D(EEL(-2))							-0.54*	-4.08
D(EEL(-3))							-0.34*	-3.07
CointEq(-1)	-0.27*	-4.09	-0.72*	-3.90	-0.70*	-4.85	-0.31***	-1.92

Note: *, **, ***indicates significance at 1%, 5% and 10% critical values.

adjustment. The error correction term shows that in case of POL products equilibrium is recuperated in about four years followed by electricity demand which takes three years to readjust. In case of natural gas and coal, about sixteen months are needed to restore equilibrium.

D stands for first difference operator, YPC for real GDP per capita, TI for trade openness, EC for coal consumption, EEL for electricity consumption, TO for trade openness, P for energy price and D(_(-1)), D(_(-2)) represents lag order such as first lag and second lag respectively.

4.5 Post Estimation Diagnostics

The adequacy of the estimated results has been endorsed through various diagnostic tests, including ARCH test, LM test, Jorque-Berra test and Ramsey Reset test. These results are reported in Table 6 which confirms the validity of our model. It implies absence of problems such as heteroscedasticity, serial correlation, and mis-specified functional form. Furthermore, adjusted R-square and the result regarding residuals normality has also been reported to show that models are well fitted.

5. Summary and Conclusion

This study investigated the demand for energy in the light of technical innovations and increasing level of openness. Using ARDL bound testing approach, this study has found that the variables are cointegrated and there exists long-run relationship. The long-run coefficients for various energy demand functions indicate that energy demand at aggregate and disaggregate levels is generally income as well as price inelastic implying that energy products are necessities. In contrast to theoretical predictions TI seems to be the main driver of energy demand in the country, except petroleum products, highlighting the existence of rebound effect.

The short-run dynamics of the energy demand at various levels confirm that GDP per capita is the major determinant of energy demand in the

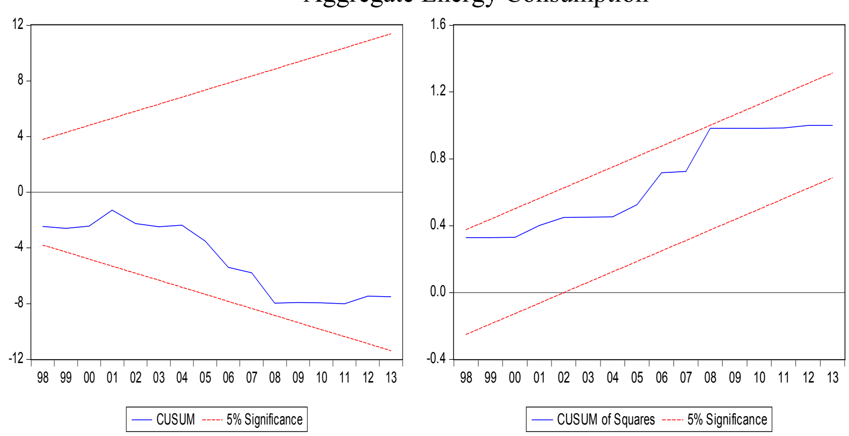
Table 6
Diagnostic Tests

		Heteroscedasticity		Serial Correlation		Normality		Functional Form	
Energy Consumption	R^2	χ^2-statistics	p-value	F-statistics	p-value	Jorque_Berra	p-value	F-statistics	p-value
Aggregate	0.99	16.86	0.77	2.12	0.157	4.08	0.18	0.03	0.85
Petroleum Products	0.98	0.046	0.83	1.34	0.28	1.08	0.56	2.39	0.13
NaturalGgas	0.95	2.735	0.11	2.59	0.12	1.54	0.67	0.02	0.89
Electricity	0.98	0.208	0.65	1.93	0.18	3.75	0.15	2.12	0.14
Coal	0.95	1.037	0.32	0.96	0.39	0.47	0.78	4.12	0.08

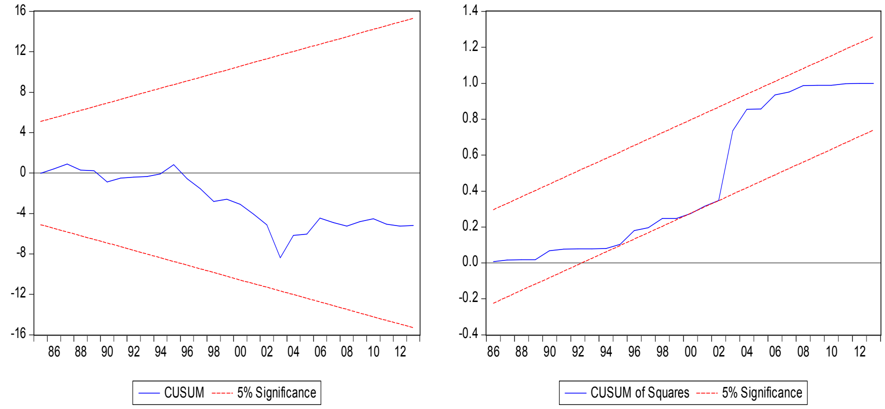
country. Energy prices again seem to be of no importance in determining energy demand except for coal. Trade openness through larger trade volume positively affects electricity and coal consumption leaving other components unaffected. TI significantly increases the demand for petroleum products and electricity demand while it does not have any significant impact on natural gas consumption in the short-run.

On the whole, the results support the feedback hypothesis in case of aggregate energy consumption and real GDP per capita and similar results are found for coal consumption also. The consumption of electricity, natural gas and petroleum products have uni-directional relationship with real output. These findings have some important policy implications. As the demand for individual products except coal is price inelastic at any horizon which has clear implications for energy products pricing policies, revenue generation and scope for demand management policies to rationalize consumption of individual energy resources to correct the existing energy mix and to overcome the existing acute energy shortfall. Moreover, the inverse association between energy consumption and trade openness for Pakistan implies that trade openness promotes energy efficiency through technological diffusion hence more efficient technology can be transferred through attracting FDI in various energy intensive sectors.

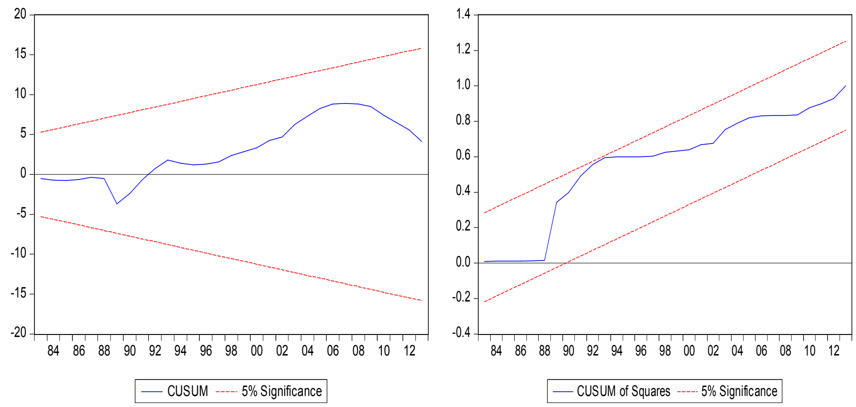
Aggregate Energy Consumption



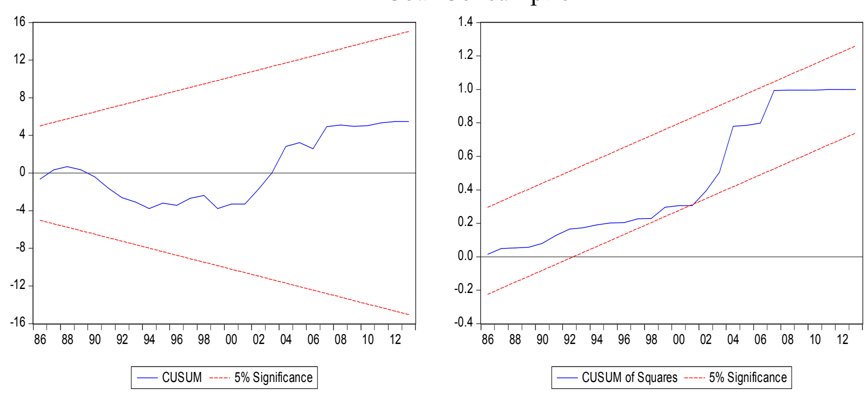
Petroleum Products Consumption



Natural Gas Consumption



Coal Consumption



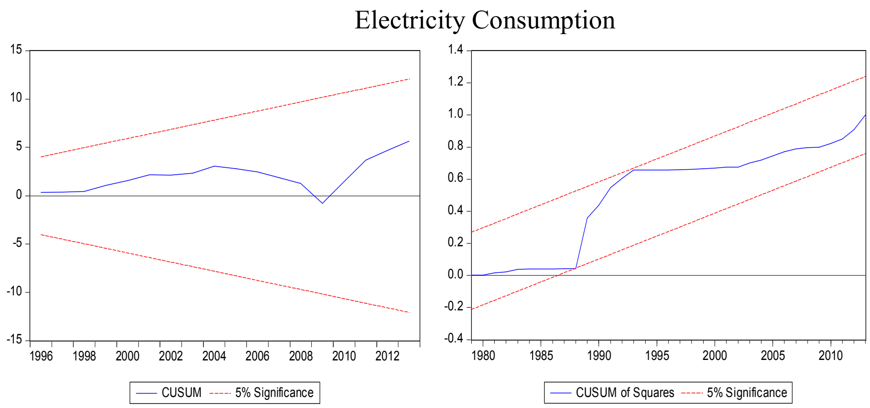


Fig. 1 Stability test for Aggregate, Electricity, Coal, Natural gas and Oil consumption functions.

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