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Interaction Between Energy Consumption and Economic Growth: Empirical Evidence from Pakistan

Oshin Khan[1] & Muhammad Zeeshan Younas*[2]

[1,2]*Quaid-i-Azam University, Islamabad, Pakistan*

Abstract. Energy arguably plays a substantial part in the economic growth process. Henceforth, a bulk of studies have endeavored to examine the linkages between energy consumption and economic growth; however, no consensus emerged. Current study is an attempt to explore the long run ties for energy consumption and energy intensity with economic growth, urbanization, trade openness, and financial development by employing ARDL cointegration in case of Pakistan for the period of 1985 to 2017. Results postulate that trade openness has a positive impact on energy consumption, while urbanization and financial development have a negative influence. As far as sectoral analysis is concerned, agriculture and manufacturing share has a positive impression on energy while the services sector has a negative effect.

Key words: Energy Consumption, Financial Development, Urbanization, Trade Openness, Economic Growth

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1 Introduction

Energy is recognized as fuel for industrial development and economic growth (Adams et al., 2019). The energy industry, along with its vital products, serves as an imperative factor in the production process of good and service and the main contributor to sustainable economic growth. Since the start of industrialization, the swift pace of economic growth is accompanied by a hefty energy consumption. By increasing wages and boosting urbanization, industrialization creates a further increase to energy demand. For example, energy consumption augmented by more than 150% during last decade in China, is documented as the worlds biggest energy user in 2017. However, the use of energy, especially that of fossil fuel, has many hostile environmental impacts. The energy consumption in terms of renewables is a note-worthy supplier to static greenhouse gas emissions. They are indispensable to keep the temperature of the earth warm. On the other side, the use of greenhouse gases caused by man-made actions, captivate more heat and lead to global warming. It causes climate change which has been documented as an extreme challenge for policymakers. The global climate change intimidates the wellbeing of society, decreases economic development and alters the natural environment. So it becomes a key concern of policymaking of current century.

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*Corresponding author.
Email: mrzee38@yahoo.com

The potential for renewable energy technologies to fill the gap between supply and demand of energy in Pakistan is dynamic. Furthermore, decentralized renewable energy splanshas the incentive to deliver electricity to rural and remote zones, in that way, assisting to ease poverty and decreasing the prerequisite to collect and burn biomass fuel for energy scarcities. With a shortage over 5000 megawatt (MW) and continuously snowballing energy prices due to high fuel prices, the demand of sustainable, cheap, and clean energy is important for decreasing dependency on imported energy means. Like other developing economies, primary energy consumption has elevated 80 percent in the previous two decades in Pakistan.

There has been a plethora of research conducted by the scholars for exploring the connection between economic growth and energy consumption but no serious attempt has yet been made with the perspective of sectoral analysis in Pakistan. Growth has different sectors, i.e. agricultural, manufacturing and services sector; each of these sectors contribute differently to energy use. Similarly, trade openness in Pakistan has different dimensions, for instance, scale effect, technique effect and comparative advantage effect, which contribute differently to energy use as well. These are the key areas of interest in this study.

The prime objective of this study is to discover the dynamics of the sector-wise impact of the economy on energy consumption. The three sectors taken are the agricultural, manufacturing and services sector. Technology in the form of comparative advantage is also taken as a factor to impact energy use. Financial development, urbanization and environmental quality, all these combine to affect energy use and so it can portray a larger image to conduct the study for the sake of Pakistan. To make the study more inclusive, the effect of trade openness is checked, with the help of three different dimensions of trade openness, i.e. Scale effect, Technique effect, Composition effect, and comparative advantage effect. The aim is to check which sectors among the growth sectors would lead to more energy consumption and which strategy might be adopted in trade to diminish environmental pollution and hence, energy consumption can be handled in this way.

2 Literature Review

In the last decade or two, plenty of studies had been conducted by the researchers that found the causal nexus between energy consumption and economic growth; mostly, the proxies used for these two are income and employment, respectively. The findings have been ambiguous and conflicting (Alvarez-Herranz et al., 2017). The first of the groundbreaking study done was by Kraft and Kraft (1978) which inferred that there is a causality from GNP to energy consumption in US. In the same way, Akarca and Long II (1979) took monthly data of US, found a unidirectional Granger Causality from energy consumption to the employment, having no feedback. These findings have been challenged by many researchers, since then. Empirical evidences provided by Erol and Yu (1987); Yu and Choi (1985) found no causal link between energy consumption and GNP (a proxy for income).

Another strand of literature analyzed this issue from another perspective as Kalimeris et al. (2014) reviewed the energy to GDP causality using a meta-analysis approach, which is quite different; 158 studies have been taken for a period of 1978-2011. Multinomial logistic regression method results do not indicate the presence of direction of causality. It rejects the neutrality hypothesis. For the sake of Pakistan, Aqeel and Butt (2001) investigated the association of energy consumption to both the economic growth and employment in Pakistan. The methodology used was co-integration and Hsiao's Granger causality. Results indicated that total energy consumption as well as that of petroleum is caused by economic growth. The reason for these conflicting empirical findings lies in the choice of approaches and methodologies used for this study. In order to proceed with the advancement in time series data, in the last decade, bivariate causality tests have been used but these also have conflicting results.

The connection between economic growth and financial development is quite complex. Sadorsky (2011) studied the impact of financial development on energy consumption for nine European nations. Results confirmed the statistically significant and positive relationship between energy consumption and financial development. Whereas, Çoban and Topcu (2013) studied the effect of financial development on consumption of energy in the europe. GMM based results do not contain any significant nexus but there is a strong proof of the effect of financial development on the energy consumption in the members that are old, irrespective of stock market or banking sector. For the new members, the same impact is dependent on the way the financial development is measured. Similarly, Furuoka (2015) took the nexus between energy use and financial development for the period of 1980-2012. Heterogeneous panel causality test described a long run equilibrium relationship between energy use and finance. The heterogeneous panel causality test further showed causality that is unidirectional and that runs from energy consumption to financial development.

Further extention in analysis made by Farhani and Solarin (2017) by examining the time series data of United States. The results suggested co-integration among them. Also, financial development lessens demand of energy in the long run but also stimulates in the short run. Nasreen et al. (2017) aimed to study the nexus between financial stability, carbon dioxide emissions, energy consumption and economic growth for South Asian countries. Granger causality and bounds tests for co-integration result expressed that the environmental quality is improved by financial stability. As far as energy intensity is concerned, Voigt et al. (2014) studied the trends in energy intensity in 40 foremost economies. At the country level, the improvements in energy intensity are largely caused by the technological change. While at a global level, there is a shift of global economy to more energy intensive countries but still, aggregate energy efficiency is followed and improved by technological change. Likewise, Adams et al. (2019) attempted to find out how to decompose the energy consumption and energy intensity into activity and efficiency changes. Fischer Ideal Index decomposition method suggested that energy intensity has been increasing to 53 percent between 1972-2011. Around 72 percent of this increase is due to the inefficient use of energy.

On the other hand, Tugcu and Topcu (2018) studied the nonlinear relationship between energy consumption and trade. Heterogeneity is involved to employ a panel framework and cross sectional dependence is checked. The sample used is of OECD countries from 1990-2015. Outcomes displayed that the effect of trade on energy consumption reveals an inverted U-shaped pattern and the nonlinear relationship is robust to estimation methods. Moreover, Wang et al. (2017) extended the analysis and empirically investigated the impact of urbanization on energy consumption taking into account the provincial differences. The results say that urbanization increases CO_2 emissions but it is not the case always. Urbanization strongly affects the regional CO_2 emissions in Northern China where there is a coal and heavy industry base.

In a nutshell, after keen evaluation of plethora of literature on economic growth and energy consumption, we divided the current study analysis into four different models with different explanatory variables taken into account. Conceptual discussion is provided in the next section.

3 Theoretical Framework And Methodology

3.1 Theoretical Framework

Energy demand and its consumption has crucial role for a country. It is not confined to country but has global impacts and consequences as well. This study investigates the relationship between economic growth and energy consumption for Pakistan. It also incorporates the consequences that environment of Pakistan faces. When energy burns, it releases dangerous chemicals, which harm the entire atmosphere and specifies living and breathing under that environment. We estimated four different models, first of which examines effects of financial development, income, urbanization and trade openness on energy demand. Since liberalization of financial markets tend to promote growth, hence following Bekaert and Harvey (2000), we have the following model to estimate impacts of financial development and income on energy demand.

$$ED = f(FD, GDP)$$

Where ED stands for energy demand, FD stands for financial development and GDP indicates gross domestic product. Similarly, urbanization has been witnessed to increase the energy consumption, i.e. the more the urbanization, the higher is supposed to be the energy consumption. Hence forth, we would be taking urbanization as control variable and augment our model as below:

$$ED = f(FD, GDP,\ UR)$$

Where UR indicates urbanization. Sbia et al. (2014) points out that another control variable which is supposed to have an impact on energy consumption is trade openness. Trade openness can have positive as well as negative impacts on energy consumption. Its impact can be negative if increasing trade flows result in bringing innovative technologies, while positive when it increases the scale of production. Thus we are augmenting our model as follow:

$$ED = f(FD, GDP, GDP^2\ UR, TR) \tag{1}$$

Where TR indicates trade openness. Similarly, we also added square of the GDP to account for Kuznets Curve for energy consumption.We further want to explore the sector wise impact of income on energy use, following Ling et al. (2015), we estimated another model by including the share of agriculture, manufacturing and services sector. For this purpose, we estimate the following model:

$$ED = f\{FD, MS, AS, SS, UR,\ TR) \tag{2}$$

Where, FD is financial development, MS, AS and SS are manufacturing shares, agriculture shares and services shares, respectively. To look further into determinants of energy demand, we took into account more of the research work. Literature further recommends that trade openness encourages mass awareness to demand for clean environment, energy-efficient technology transfer and government policy course toward ecological welcoming programs. The environmental significance of trade via energy consumption is varied by income effect, technique effect, and composition effect (Jena and Grote, 2008).

$$ED = f(GDP, GDP^2, K, TR, K.TR) \tag{3}$$

Where GDP, GDP2 are gross domestic product and its squared and they show scale effect and technique effect, respectively. K is capital-labor ratio represents composite effect, TR is trade openness, which depicts trade effect, while K.TR is comparative advantage effect.

$$EI_t = f(GDP, Krate, K/L) \tag{4}$$

Where EIt is energy intensity, It is ratio of energy use to GDP, while K denotes capital growth rate and K/L is ratio of capital and labor. We have taken energy intensity as dependent variable to check its determinants. However, we used GDP and capital growth rate and capital-labor ratio as explanatory variables. Variable of GDP is included to show the level of economic development. There is general belief that as economy develops energy efficiency also improves, so accordingly we expect GDP sign for model (4) to be negative. Following Thompson and Taylor (1995) and Metcalf (2008), capital-labour ratio is used as a proxy for level of technology. The intuition is that technology, energy and capital can be substituted. However, we expect capital-labour ratio to have a negative sign, since energy intensity may lower energy use because of improvements in the technologies. We also introduced the growth of capital stock in the model which is used to account for the speed by which old machines are replaced by new ones.

3.2 Econometric Methodology

Our main emphasis is to estimate dynamics of energy consumption for country Pakistan, and since we have to deal with time series data, it has its own problems and properties. One of the most important properties of the time series is data stationarity, it must be checked otherwise simple ordinary least squares (OLS) will provide spurious coefficients. Fortunately, researchers have found the way to deal with this type of problem, if variables are non-stationary or there exists unit root in the series, they prefer to estimate co-integration techniques to estimate any relationships given variables and models.

Co-integration is broader concept under which comes different techniques, few of them are widely used based on their popularity, which are single equation approaches including residual based Engle-Granger single equation technique (Engle and Granger, 1987) and ARDL technique (Pesaran et al., 2001) and multiple equation approaches which include Johanson-Juselius (JJ) technique (Johansen and Juselius, 1990). Since we are interested in finding our dynamic relationship among variables, this study will apply ARDL approach to co-integration.

Speaking of ARDL technique, it is superior to other mentioned integrated techniques. Firstly, ARDL is flexible as compared to other approaches, that is, when order of integration is not same. i.e. some are I(1) and some are I(0), it can also be employed. In contrast, ARDL should not be used if any of the variables are integrated of order two, symbolically, I(2). Its flexibility also includes introduction of lags of both dependent and independent variables in the model, when lags of dependent variable are incorporated it is called autoregressive; while inclusion of lags of independent variables makes it "distributed lag", thus, allows past values to impact dependent variable. Secondly, when ARDL takes sufficient number of lags, it uses general to specific framework to deal with and to capture data generating process. Moreover, estimates using ARDL are consistent if there is a short span of data. To attain optimal lag length, ARDL estimates the expression of (p+1) K number of regression. In the mentioned expression, k denotes number of variables, while p denotes maximum lags.

Thirdly, ARDL is relatively robust when sample size is finite or small. According to Pesaran and Shin (1998), ARDL is superior in case of small sample on Johansen co-integration technique, which requires sample to be large enough to produce valid and reliable results. In addition to that, the techniques of Johansen and Juselius (1990) and Engle and Granger (1987) do not yield reliable results in small sample case. Briefly speaking, in situation involving endogeneity, small size of sample and varying order of integration among variables, ARDL approach given by Pesaran et al. (2001) is used to find out short and long run connections among various variables.

3.2.1 Econometric Models of the Study

Based on availability, data on respective variables are taken from 1985 to 2016 for Pakistan. Since Pakistan is facing energy shortage against achieving its desired energy needs, so it will be interesting to study case of Pakistan. Complete variables description and data sources are presented in the appendix section of this study. Econometrical models of the study are described below:

Model 1

$$lnEU_t = \beta_0 + \beta_1 lnFD_t + \beta_2 lnGDP_t + \beta_3 lnGDP_t^2 + \ \beta_4 lnUR_t + \beta_5 TR_t + {}_t$$

Model 2

$$lnEU_t = \gamma_o + \gamma_1 lnFD_t + \gamma_2 lnAS_t + \ \gamma_3 lnMS_t + \gamma_4 lnSS_t + \gamma_5 lnUR_t + \gamma_5 lnTR_t + \mu_t$$

Model 3

$$lnEU = \alpha_0 + \alpha_1 lnGDP + \alpha_2 lnGDP_t^2 + \alpha_3 lnK\_L_t + \alpha_4 lnTR_t + \alpha_5 lnK.TR_t + \mu_t$$

Model 4

$$lnEI_t = \beta_0 + \beta_1 lnGDP + \beta_2 lnKrate + \beta_3 lnK\_L_t + \mu_t$$

Where ln denotes natural logarithm, $\alpha_0,\ \gamma_o, \beta_0$ are intercepts, while $\beta' s,\ \gamma' s$ and α's are coefficients of respective variables. lnFD is natural log of financial development, lnGDP is natural log gross domestic product, lnUR is natural log of urbanization, lnTR is natural log of trade openness. lnAS is natural log of agriculture share, lnMS is natural log of manufacturing share lnSS is natural log of services sector, lnK_L is natural log of capital-labour ratio while lnK.TR is comparative advantage and lnKrate is growth rate of capital. The general form for ARDL model is:

$$\triangle E_t = \alpha_0 + {}_1 E_{t-1} + \alpha_2 GDP_{t-1} + \alpha_3 FD_{t-1} + \alpha_4 TR_{t-1} + \alpha_5 UR_{t-1} + \alpha_6 \sum_{i=1}^{p} \triangle E_{t-i} + \alpha_7 \sum_{i=0}^{p} \triangle GDP_{t-i} + \alpha_8 \sum_{t=0}^{p} \triangle FD_{t-i} + \alpha_9 \sum_{t=0}^{p} TR_{t-i} + \alpha_{10} \sum_{t=0}^{p} UR_{t-i} + \varepsilon_t \quad (5)$$

Where α_0 is intercept parameter while $\alpha_1$to α_{10} on right hand side are long run parameters indicating long run relationship. p shows number of lags, ε_t is error term which is white noise in the model. The terms along with delta sign and summation show error correction estimates for short run. There are two steps in ARDL approach for calculating F-statistics for co-integration. First is the selection of lag length of the ARDL model, thus optimal number of lags must be selected before estimating ARDL model. There are different criterion for selection of optimal number of lags such as Akaike Information Criterion (AIC), Schwarz Information Criterion (SC), Log Likelihood Ratios (LR) and Log Likelihood test (LL). These all criterion have same null hypothesis that is, selected order of lag is optimal.

Once number of optimal lags are selected, we will go for second step of ARDL approach, which is to find out long run relationship of selected ARDL model. Prior to this, we will make use of Wald or F-test (Pesaran, 1997). Wald test is applied when we need to test for the significance of lagged levels of the variable. The variables which are incorporated in the unrestricted equilibrium error correction model. Speaking of statistical hypotheses, Wald test has null hypothesis of no co-integration exists among the variables, while alternative hypotheses are:

$H_0 : \alpha_i = 0, \qquad H_1 : \alpha_i \neq 0$

Pesaran et al. (2001) suggested critical values of F-statistics, which are used to make decisions, these values have I(0) and I(1) data generating process. Thumb rule for decision making for this test is: If calculated value of F-statistics is greater than tabulated/critical values of I(1), i.e. upper bound, we reject null hypothesis meaning that there exits long run relationship. While if calculated value for F-statistics is less than that of critical/tabulated values of I(0), i.e. lower bound, we accept null hypothesis meaning that there exists log run relationship among variables. Moreover, result may be inconclusive if calculated values lie in between upper bound I(1) and lower bound I(0). This is the reason for ARDL as not valid technique for I (2), because it has only two bounds. Once we have successfully applied Wald test, and found that there exits long run association among variables, we will move to our next step which is to estimate long run coefficients using ARDL model equation 5. When we attain long run coefficients of the ARDL model for our variables, we may estimate short run coefficients as well. For short run analysis, it is necessary to retrieve error correction model from ARDL through linear transformation. The interesting fact regarding error correction model is that it integrates short run adjustments with long run, and luckily does not lose information. The main purpose of ECM is to give information about speed of adjustment or say convergence of dependent variable after short run disturbances in independent variables towards long run equilibrium. Lower the value of coefficient of error correction term slower the speed of adjustment and vice versa. Another fact regarding error correction term is that it must be negative and significant at high level of significance, which indicates that long run relationship is achievable among variables. ECM along with short run coefficient takes the form:

$$\triangle E_t = \alpha_0 + \alpha_1 ECM_{t-1} + \alpha_2 \sum_{i=1}^{p} \triangle E_{t-i} + \alpha_3 \sum_{i=0}^{p} \triangle GDP_{t-i} + \alpha_4 \sum_{t=0}^{p} \triangle FD_{t-i} + \alpha_5 \sum_{t=0}^{p} \triangle TR_{t-i} + \alpha_6 \sum_{t=0}^{p} \triangle UR_{t-i} + \varepsilon_t \quad (6)$$

Lastly but most importantly, diagnostic tests have vital importance since they diagnose problem regarding model specification and data used. Therefore, we have applied different diagnostic tests such as test for serial correlation, functional form, heteroskedascity and normality of residuals. These diagnostic tests include Ramsey RESET test, which tells whether functional form of model we have estimated is correct. Breusch Godfrey serial correlation LM test, which is very useful and widely used for checking serial correlation. For normality of residuals we have used Jarque-Berra test. In last, presence of heteroskedascity is checked via applying ARCH test. To check whether our model is structurally stable Pesaran (1997) recommend use of CUSUM and CUSUMSQ tests proposed by Brown et al. (1975), which are widely used to check stability of model. Rule of thumb here is that, if these plots lie within the critical bounds at 5% level of significance, we cannot reject null hypothesis rather we accept it, and conclude that our model is stable. Null hypothesis is "all the coefficients in given regression are stable".

4 Results and Empirical Analysis

First part of this section presents graphical representations of dependent variable, i.e. energy consumption against all other explanatory variables to discover patterns and/or trends of variables. Fig 1 exhibits relationship between energy use and agriculture sector, trend is positively sloped indicating positive relationship. Fig 2 shows relationship between energy use and labour force, likewise, there is positive pattern shown by graph. Fig 3 depicts financial development against energy use, shows negative trend between these two. Fig 4 shows relationship between energy use and GDP which is also positively sloped, similarly, fig 5 and fig 6 depict energy use against manufacturing sector and capital respectively. Both tend to show positive pattern. Fig 7 shows positive relationship between energy use with services sector while Fig 8 shows negative trend between energy use and trade. Fig 9 exhibits positive pattern for urbanization against energy use.

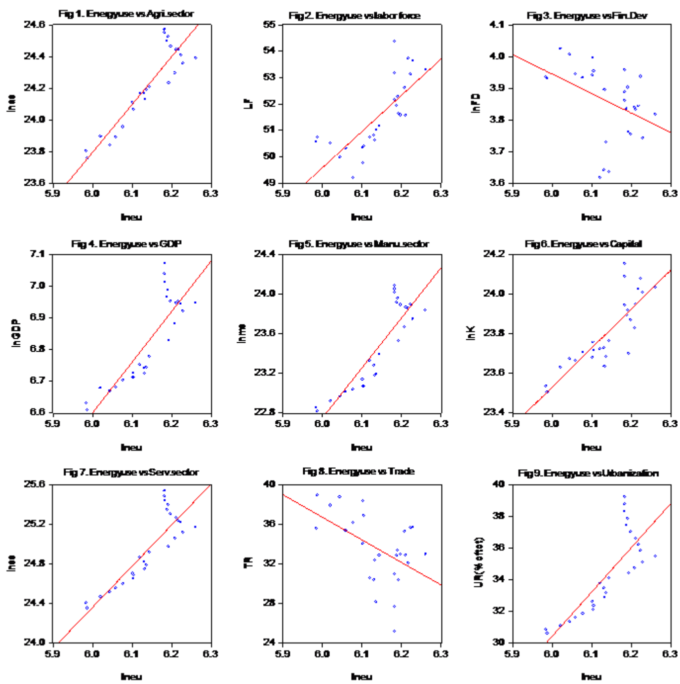

Figure 1: Research Model

Table 4.1: Risk Register

	LNEU	LNAS	LF	KRATE	K_TR	K_L	LNFD	LNGDP	LNGDPSQR	LNMS	LNSS	TR	LNUR
Mean	6.141543	24.2216	51.52483	2.8444	15.48654	0.462355	3.857081	6.826521	13.65304	23.46551	24.9466	33.46264	34.38519
Median	6.144151	24.20805	51.16713	3.199175	15.2538	0.464314	3.886971	6.778149	13.5563	23.39228	24.91534	32.99043	34.065
Maximum	6.26104	24.57409	54.37153	19.90113	18.35536	0.481903	4.023913	7.072251	14.1445	24.08885	25.53582	38.90949	39.224
Minimum	5.984615	23.75421	49.19157	7.705547	11.16847	0.444266	3.616726	6.609082	13.21816	22.81563	24.34812	25.13914	30.576
Std. Dev.	0.075437	0.253745	1.36099	6.762113	1.76638	0.009345	0.113975	0.140222	0.280445	0.429325	0.360725	3.460577	2.613814
Skewness	-0.58545	-0.26714	0.435549	0.551135	-0.30055	-0.10125	-0.66737	0.161627	0.161627	0.004416	0.012432	-0.39825	0.285807
Kurtosis	2.42394	1.901495	2.195486	3.227976	2.874349	2.489324	2.539357	1.588741	1.588741	1.439812	1.738119	2.766747	1.894614
JarqueBera	1.91572	1.678688	1.581811	1.425344	0.424238	0.339518	2.24296	2.358162	2.358162	2.738547	1.792082	0.774928	1.7422
Probability	0.383713	0.431994	0.453434	0.490332	0.808868	0.843868	0.325797	0.307561	0.307561	0.254292	0.408183	0.678776	0.418491

Table 4.2: Risk Register

	Lneu	*lnFD*	*TR*	*lnGDP*	*lnGDPsqr*	*lnms*	*lnas*	*lnss*	*LF*	*lnK*	*K/L*	*K.TR*	*Lnur*	*Krate*
lneu	1													
lnFD	-0.40844	1												
TR	-0.49789	0.480873	1											
lnGDP	0.86015	-0.17153	-0.57394	1										
lnGDPsqr	0.86015	-0.17153	-0.57394	1	1									
lnms	0.888682	-0.25581	-0.57754	0.992266	0.992266	1								
lnas	0.898947	-0.31033	-0.65019	0.96952	0.96952	0.976291	1							
lnss	0.869575	-0.26594	-0.63719	0.988246	0.988246	0.991693	0.989263	1						
LF	0.762291	-0.17197	-0.50205	0.853262	0.853262	0.848789	0.790053	0.811432	1					
lnK	0.835353	-0.09292	-0.47441	0.936037	0.936037	0.918793	0.887777	0.903808	0.861293	1				
K/L	-0.6833	0.199851	0.47947	-0.76277	-0.76277	-0.76541	-0.70116	-0.72233	-0.97984	-0.74329	1			
K.TR	-0.57559	0.482114	0.987211	-0.65248	-0.65248	-0.65825	-0.71288	-0.70365	-0.62728	-0.55708	0.612068	1		
lnur	0.807579	-0.22955	-0.66117	0.979729	0.979729	0.977007	0.974208	0.992916	0.790883	0.879284	-0.70488	-0.72106	1	
Krate	-0.00744	0.059108	0.067882	0.110239	0.110239	0.067789	0.023597	0.044996	0.288841	0.2102	-0.29051	0.011803	0.047165	1

We have applied ADF unit root test on all variables to find out whether our variables are stationary and in case if they are not stationary, on what difference they will become stationary, in other words, known the order of integration. The results are presented in table 3.

Table 4.3: ADF Unit root test

Variable	**At level**			**At first difference**			**Order**
	Cal-value	**Critical-value**	**P-value**	**Cal-value**	**Critical-value**	**P-value**	
lnEU	-2.38152	-2.98104	0.1563	-3.73451	-2.98623	0.0098***	I(1)
lnFD	-1.63501	-2.98104	0.4511	-4.16246	-2.98623	0.0036***	I(1)
lnGDP	0.914933	-3.01236	0.9936	-3.04071	-2.98623	0.0447***	I(1)
lnGDPsqr	0.914933	-3.01236	0.9936	-3.04071	-2.98623	0.0447***	I(1)
lnAS	-1.54034	-2.98104	0.4978	-5.6318	-2.98623	0.0001***	I(1)
lnMS	-0.66283	-2.98623	0.8386	-2.97619	-2.98623	0.0510**	I(1)
lnSS	-0.08327	-2.98623	0.9411	-3.1085	-2.98623	0.0388***	I(1)
lnLF	-0.51608	-2.98104	0.8727	-4.58869	-2.98623	0.0013***	I(1)
lnTR	-1.46633	-2.98104	0.5343	-6.08777	-2.98623	0.0000***	I(1)
lnUR	-0.5968	-1.95568	0.4482	-2.60835	-1.95568	0.0115***	I(1)
lnK_L	-0.99888	-2.98104	0.7383	-5.1374	-2.98623	0.0003***	I(1)
lnK.TR	-1.2174	-2.98104	0.6511	-6.13611	-2.98623	0.0000***	I(1)
Krate	-3.58643	-2.98104	0.0133***	-	-	-	I(0)

Table 4.4: Lag Order Selection Criteria

Model 1						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	302.7398	NA	1.97e-18	-23.73918	-23.44665	-23.65805
1	540.7985	342.8045	2.07e-25	-39.90388	-37.85616	-39.33593
2	640.1691	95.39587*	2.33e-27*	-44.97353*	-41.17064*	-43.91877*
Model 2						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	156.4659	NA	1.51e-14	-11.95727	-11.61599	-11.86262
1	351.3361	265.0234	1.52e-19	-23.62689	-20.89661	-22.86962
2	482.0801	104.5952*	6.89e-22*	-30.16641*	-25.04713*	-28.74654*
Model 3						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	255.9239	NA	8.36e-17	-19.99391	-19.70138	-19.91277
1	376.8753	174.1701	1.02e-19	-26.79002	-24.74231	-26.22208
2	446.4181	66.76113*	1.25e-20*	-29.47345*	-25.67056*	-28.41869*
Model 4						
Lag	LogL	LR	FPE	AIC	SC	HQ
0	119.8341	NA	3.14e-10	-10.53037	-10.33200	-10.48364
1	193.3696	113.6458	1.73e-12	-15.76087	-14.76902	-15.52722
2	218.2210	29.36984*	9.21e-13	-16.56555	-14.78020	-16.14497
3	236.6076	15.04360	1.22e-12	-16.78251	-14.20368	-16.17502
4	282.0807	20.66955	3.17e-13*	-19.46188*	-16.08956*	-18.66746*

** indicates optimal lags selected by specified criterion.*

Since we are following the results of ADF test, it concludes that all variables are stationary at first difference, I(1), for which ARDL technique to cointegration can be applied. Since we have selected optimal lag criteria based on AIC, which is two optimal lags for models 1, 2 and 3 while four optimal lag for model 4. Bound Test is used in order to analyse the long run relationships and examine whether cointegration exist or not. So Bound-test is applied on four models and results are presented in following table, which shows calculated f-values along with lower and upper bounds critical values. Table shows that for model (1) calculated F-value is 13.19193, lower bound 2.62 and upper bound 3.79. When all variables are order of integration I(0), then decision should be made on lower bound, whereas, if all variable of order I(1), we should decide on upper bound I(1). Since our all variables are stationary at 1st difference or say are of order of integration I(1), we compare our calculated f-value with upper bound critical value. However, it can be concluded that there exits long run relationship among variables in our estimated model

(1) i-e calculated F-value is greater than upper bound.

Table 4.5: Bound Test at 5% significance level

	Calculated F-value	**Critical lower bound I(0)**	**Critical upper bound I(1)**	**Result**
Model 1	13.19193	2.62	3.79	Cointegration
Model 2	9.110683	2.45	3.61	Cointegration
Model 3	4.158414	2.62	3.79	Cointegration
Model 4	4.26063	3.23	4.35	Cointegration

4.1 Results of Long-Run Estimates (ARDL Model)

This sub-section reports results for long run estimates of ARDL model. Following table shows explanatory variables along with their respective coefficients, t-statistics and probability. Energy consumption (lnEU) is used as dependent variable for models (1,2 and 3). Reporting results for model (1) describe that coefficient of financial development has negative sign while GDP is positive. Squared term of GDP is also significantly negative alongwith Urbanization at 1% level of significance. Coefficient of trade openness has positive sign but it is insignificant variable indicating that trade openness does not significantly affect energy consumption. Value of adjusted R2 for model (1) indicates model is pretty appropriate and fit as it explains 0.994019 variation in the model that is model predicts responses for new observations.

Table 4.6: Long Run Coefficients

Model 1 Dependent variable (lnEU)			
Variable	Coefficient	t-Statistic	Prob.
LNFD	-0.09559	-3.43978	0.0088
LNGDP	28.34371	9.719116	0
SQRLNGDP	-1.99597	-9.27861	0
LNTR	0.027455	0.944657	0.3725
LNUR	-0.59673	-5.17139	0.0009
C	-91.6268	-9.39514	0
Adjusted R2		0.994019	
D. Watson statistics		2.957943	
Model 2 Dependent variable (lnEU)			
Variable	Coefficient	t-Statistic	Prob.
LNFD	0.072666	1.874132	0.11
LNAS	0.296844	3.230479	0.0179
LNMS	0.227504	4.867763	0.0028
LNSS	-0.37203	-4.59649	0.0037
LnUR	-0.17439	-4.84166	0.0029
LnTR	0.000905	0.535597	0.6115
C	3.112022	3.613225	0.0112
Adjusted R2		0.989947	
D. Watson statistics		3.077529	

Model 3 Dependent variable (lnEU)			
Variable	Coefficient	t-Statistic	Prob.
LNGDP	55.02006	13.66525	0
LNGDPSQR	-4.00228	-13.5212	0
K_L	-9.9747	-4.20679	0.0023
LnTR	-0.11315	-3.65109	0.0053
K_TR	0.249181	3.687336	0.005
C	-178.339	-13.7252	0
Adjusted R2	0.988735		
D. Watson statistics	2.49295		
Model 4 Dependent variable (lnEI)			
Variable	Coefficient	t-Statistic	Prob.
LNGDP	-0.11554	-6.85848	0.001
K_L	-0.825229	-2.968843	0.0312
KRATE	-0.001281	-3.53068	0.0167
C	2.071748	9.873514	0.0002
Adjusted R2	0.976843		
D. Watson statistics	2.333951		

For model (2), variables such as agriculture share, manufacturing share, services share and urbanization are significant at 1% level of significant while financial development and trade openness are insignificant. Value of adjusted R2 is appropriate suggesting that model explains variation and responses to new observation as well. Findings for model (3) show that, all variables used in the models are significant at 1% level of significance. Similarly, for model (4) all variables are significant at 1% level of significance and all variables have negative signs.

4.2 Results of Error Correction Model (ECM)

We have extracted short run coefficients using error correction model which are reported in the following table. Error correction term (ECM) has vital importance in case of short run, since it shows speed of adjustment or say convergence, to put it in simpler words, it tells how long it will take for variable to converge. For model (1), ECM has value -0.692655 at 1% level of significance in short run. It has implication that any shock will be corrected if it occurs in energy consumption by taking 69 percent speed in course of one year. Similarly, for model (2) value of ECM is -0.171864 at 1% level of significance. As well, model (3) has ECM value of -1.048985 at 1% level of significance indicating any shock will be adjusted in energy consumption by speed of 105% in course of one year. For model (4), ECM has value -0.602722 at 1% level of significance in short run. It shows that any shock will be adjusted if it occurs in energy intensity by taking speed of 60 percent in course of one year.

Table 4.7: Short run coefficients (ECM)

Model (1) Dependent variable = Δlneu			
Regressors	**Coefficients**	**t-values**	**Probability**
Δlneu(-1)	0.206676	1.498820	0.1723
Δ(LNGDP)	10.436003	1.351704	0.2134
Δ(SqrlnGDP)	-0.700256	-1.238103	0.2508

Δ(lnFD)	-0.055113	-1.362606	0.2101
Δ(LNTR)	-0.085653	-2.959916	0.0181
Δ(LNUR)	63.038532	2.998724	0.0171
CointEq(-1)	-0.692655	-6.706688	0.0002
Model (2) Dependent variable = ΔlnEU			
Δ(lnEU(-1))	-0.171864	-0.768660	0.4713
Δ(LNFD)	0.016844	0.451528	0.6675
Δ(LNAS)	0.134042	2.345304	0.0574
Δ(LNMS)	0.210007	2.772848	0.0323
Δ(LNSS)	0.450135	1.917656	0.1036
Δ(URGR)	0.384149	1.810363	0.1202
Δ(TR)	-0.003095	-2.642852	0.0384
CointEq(-1)	-0.171864	-5.241138	0.0019
Model (3) Dependent variable = ΔlnEU			
Δ(LNEU(-1))	-0.150361	-1.018429	0.3351
Δ(LNGDP)	22.770081	1.932933	0.0853
Δ(LNGDPSQR)	-1.651934	-1.892680	0.0909
Δ(K_L)	-9.451071	-3.786609	0.0043
Δ(TR)	-0.124388	-3.879681	0.0037
Δ(K_TR)	0.261387	3.767464	0.0044
CointEq(-1)	-1.048985	-4.511555	0.0015
Model (4) Dependent variable = ΔlnEI			
Δ(LNEI(-1))	0.221720	0.551194	0.6052
Δ(LNGDP)	-0.033037	-0.929384	0.3953
Δ(K_L)	-0.168731	-1.073350	0.3322
Δ(KRATE)	-0.000260	-1.840263	0.1251
CointEq(-1)	-0.602722	-2.458190	0.0574

4.3 Encompassing Analysis

This section reports the results of encompassing analysis which are done to find out sensitivity and robustness of variables and to mitigate specification bias problem as shown in following tables.

Table 4.8: Model 1 Dependent Variable (EU)

Variables	Eq. 1	Eq. 2	Eq. 3	Eq. 4	Base Eq.
LNFD	-0.43355***	-0.71209***	-0.419452***	7.190318	-0.09559***
	(-3.87384)	(-3.86366)	(-2.387171)	-0.025545	(-3.43978)
LNGDP		1.342625***	16.289056	272.358376	28.34371***
		-3.976537	-1.251343	-0.030342	-9.719116
SQRLNGDP			-1.114634	-20.330684	-1.99597***
			(-1.160006)	(-0.03016)	(-9.27861)
LNTR				-0.090987	0.027455
				(-0.02679)	-0.944657
LNUR					-0.59673***
					(-5.17139)

Above table reports coefficient of model 1 for variables of financial development (LNFD), gross domestic product (LNGDP), squared term of GDP (SQRLNGDP), trade openness (LNTR) and urbanization (LNUR), whereas, energy use is used as dependent variable. Coefficient of financial development is negative and significant at 1% level of significance through all equations except Eq.4 where it is positive and insignificant. GDP is positive and significant for Eq.2 and base Eq. while for Eq.3 & Eq.4. it is insignificant. Variable of squared GDP is negative throughout all equations, and significant at 1% of level of significance in base equation. Trade openness is insignificant throughout all equations, while urbanization is negative and significant at 1% level of significance. Similarly, the table 9 reports coefficients of model 2 for variables of financial development (LNFD), agriculture sector (LNAS), manufacturing sector (LNMS), services sector (LNSS), trade openness (LNTR), urbanization(LNUR). Coefficient of financial development is negative from eq 1 to eq 4. It is positive for base and eq 4. It is significant only for eq 1 and eq2 at 1 percent level of significance. Coefficient of agricultural sector is positive throughout the equations. It is negative and significant for equation 2, 5 and base eq at 1 percent level of significance. Coefficient of manufacturing sector is positive throughout the equations except for eq 3. It is significant only in the base eq at 1 percent level of significance. Likewise, the coefficient of services sector is negative in all the equations and it is significant only in the base equation. Coefficients of urbanization and trade openness are negative and insignificant except for urbanization in base equation, which is significant at 1% level of significance.

Table 4.9: Model 2 Dependent Variable (EU)

Variable	Eq.1	Eq.2	Eq.3	Eq. 4	Eq. 5	Base Eq.
LNFD	-0.43355***	-0.33248***	-0.00483	-0.100025	0.132704	0.072666
	(-3.87384)	(-4.59406)	(-0.004342)	(-0.695157)	-1.550735	-1.874132
LNAS		0.124465***	0.815514	0.108518	0.299078***	0.296844***
		(-3.386085)	(-0.501844)	(-0.10617)	(-3.40624)	(-3.230479)
LNMS			-0.794101	0.267889	0.142194	0.227504***
			(-0.462831)	-0.965477	-1.125352	-4.867763
LNSS				-0.235836	-0.043118	-0.37203***
				(-0.251744)	(-0.081365)	(-4.59649)
LnUR					-0.288477	-0.17439***
					(-0.496461)	(-4.84166)
LnTR						0.000905
						-0.535597

Table 10 reports findings for model 3, coefficients of GDP and squared GDP are significant at 1% level of significance and are positive and negative, respectively, for equations Eq.4 and baseline Eq; while coefficient of capital and labor ratio has negative sign and significant only in baseline eq. Similarly, trade openness has negative sign and significant at 1% level of significance, however, comparative advantage variable is found to be positive and significant showing that 1% increase in comparative advantage leads to 0.249% increase in energy use.

Table 4.10: Model 3 Dependent (EU)

Variable	Eq. 1	Eq.2	Eq.3	Eq. 4	Baseline Eq.
LNGDP	-0.33663	-11.804512	25.42732	45.76374***	55.02006***
	(-0.82148)	(-0.162415)	-1.442257	-8.219856	-13.66525
LNGDPSQR		0.818114	-1.84153	-3.31596***	-4.00228***
		(-0.157902)	(-1.44276)	(-8.11493)	(-13.5212)
K_L			0.002858		-9.9747***
			(-0.023486)	(-1.455)	(-4.20679)
LnTR				-0.04931	-0.11315***
				(-0.5181)	(-3.65109)
K_TR					0.249181***
					(-3.687336)

5 Conclusion

The study investigates dynamic relationships between economic growth and energy consumption via incorporating different variables such as trade oppresses, financial development, urbanization. Four different models are estimated, first three models are estimated for energy use, whereas, model 4 is estimated for energy intensity. The study employs ARDL bound test approach to discover long run relationships and concludes that there exists long run relationship for all four models. It concludes that trade openness positively related to energy use that is when country engages in trade it needs production of goods to export, which leads industries to produce more and consume more energy; while urbanization impacts negatively energy use for Pakistan suggesting that in urban areas are likely to adopt energy efficient technology. Economic growth is shown to have larger and positive impact on energy use, while financial development has negative impact on energy use. Since it is likely that financial development leads to energy and cost-efficient technologies in practical use. Among shares of economy, agriculture and manufacturing share has positive impact on energy use because these sectors need energy to produce. However, services share is shown to have negative effect on energy use, it leads to decrease in energy use. Capital to labor ratio and comparative advantage impact energy use negatively and positively.

5.1 Recommendations

The policy makers around country can look for the empirical results of this study, since it provides stages of energy use and economic growth relationship. We have witnessed a huge significant positive impact of GDP on energy use, suggesting that as GDP grows it significantly increases energy consumption. We have also found inverted U-shaped relationship between GDP and energy use, indicating that initially, as GDP grows it leads to significant increase in energy use and after achieving certain point GDP grows but energy use tends to decline. However, initial impact is larger. For Pakistan, it is unaffordable to lose or restrict growth since it is main driver of development, therefore, use of cleaner and pollution-efficient energy should be promoted all over country to mitigate negative and hazardous outcomes occurring because of massive consumption of energy usage. Moreover, government of Pakistan should consider above situation (stages) while devising and policies related to energy. Trade openness and urbanization have negative significant impact on energy use, indicating that trade brings energy efficient and eco-friendly technology, therefore, trade should be promoted, and government should design policies to increase our trade with other countries. While urbanization leads to improvement in efficient use of public infrastructure, such as local public transport, in this way it lowers energy use, thus energy use causing pollution can be reduced if government takes serious measures to improve quality of public infrastructure. Financial development is also seen to lower use of energy, argument is well-developed financial markets accelerate home investment which attracts foreign inflows along with know-how and advanced and energy-efficient technology, thus reducing energy use by improving energy efficiency. Policy makers should pay heed to encourage loans and attempt to boost financial markets, which is also good for development.

Policy makers should also take into consideration economys sectors, i.e. agriculture, manufacturing and services. Agriculture sector and manufacturing sector are seen to increase energy use, while services sector is seen to lower energy use, government should introduce energy efficient and advanced technology and different sources for energy in agriculture and manufacturing sectors to save energy resources and usage. Growth rate of capital lowers energy use, since as capital grows, it is possible it grows with advancements of technologies, so government may target on capital, and policy may be devised to promote growth of capital, which ultimately would lower use of energy. In long run, emphasis should be given to adopting energy saving methods, such as energy mitigation and energy mix choices, investment in renewable energy resources should also be focused. The major goal should be to achieve efficiency in overall energy use by improving energy infrastructure and promoting financial development, trade openness.

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Appendix

Table 5.1: Variables Summary

Indicator Name	Long definition	Unit	Source
Energy use	Energy use refers to use of primary energy before transformation to other end-use fuels, which is equal to indigenous production plus imports and stock changes, minus exports and fuels supplied to ships and aircraft engaged in international transport.	(kg of oil equivalent per capita)	IEA Statistics OECD/IEA (http://www.iea.org/stats/index.asp), subject to https://www.iea.org/t&c/termsandconditions/
Energy intensity	Ratio of energy consumption to gross domestic product.	kt of CO2 equivalent	WDI
GDP per capita	GDP per capita is gross domestic product divided by midyear population. GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products.	(constant 2010 US$)	WDI
Trade	Trade is the sum of exports and imports of goods and services measured as a share of gross domestic product.	(% of GDP)	WDI
Urban population growth	Urban population refers to people living in urban areas as defined by national statistical offices. It is calculated using World Bank population estimates and urban ratios from the United Nations World Urbanization Prospects.	(% annual)	WDI
Domestic credit to private sector	Domestic credit to private sector refers to financial resources provided to the private sector by financial corporations, such as through loans, purchases of nonequity securities, and trade credits and other accounts receivable, that establish a claim for repayment.	(% of GDP)	IFS
Manufacturing, value added	Manufacturing refers to industries belonging to ISIC divisions 15-37.	(constant 2010 US$)	WDI
Agriculture, value added	Agriculture corresponds to ISIC divisions 1-5 and includes forestry, hunting, and fishing, as well as cultivation of crops and livestock production.	(constant 2010 US$)	WDI

Services, etc., value added	Services correspond to ISIC divisions 50-99. They include value added in wholesale and retail trade (including hotels and restaurants), transport, and government, financial, professional, and personal services such as education, health care, and real estate services. Also included are imputed bank service charges, import duties, and any statistical discrepancies noted by national compilers as well as discrepancies arising from rescaling.	(constant 2010 US$)	WDI
Labor force participation rate, total	Labor force participation rate is the proportion of the population ages 15 and older that is economically active: all people who supply labor for the production of goods and services during a specified period.	(% of total) (modeled ILO estimate)	WDI
Gross fixed capital formation	Gross fixed capital formation (formerly gross domestic fixed investment) includes land improvements (fences, ditches, drains, and so on); plant, machinery, and equipment purchases; and the construction of roads, railways, and the like, including schools, offices, hospitals, private residential dwellings, and commercial and industrial buildings.	(constant 2010 US$)	WDI
Capital-Labor ratio	capital is divided by labor force to get capital-labor ratio	(%)	WDI
Comparative advantage	Capital-labor ratio multiplied by Trade openness to get comparative advantage	(%)	WDI
Gross fixed capital formation	Average annual growth of gross fixed capital formation based on constant local currency. Aggregates are based on constant 2010 U.S. dollars.	(annual % growth)	WDI

Table 5.2: Diagnostic Test Results

Model (1)		
Test	**F-statistics**	**Prob.**
Jarque-Bera Test	0.735054	0.692445
ARCH test for Hetero	0.787691	0.4685
Autocorrelation LM Test	19.95133	0.0022
Model (2)		
Jarque-Bera Test	1.344169	0.510643
ARCH test for Hetero	0.356434	0.7045
Autocorrelation LM Test	3.492315	0.1326
Model (3)		
Jarque-Bera Test	3.380483	0.184475
ARCH test for Hetero	0.019048	0.9811
Autocorrelation LM Test	2.237430	0.1773
Model (4)		
Jarque-Bera Test	1.462779	0.481240
ARCH test for Hetero	0.621148	0.6549
Autocorrelation LM Test	6.684165	0.2814