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Disaggregate Energy Consumption and Economic Growth in Pakistan: A Sectoral Analysis

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ABSTRACT

This study analyzes the relationship between disaggregate energy consumption i.e. oil, coal, gas, and electricity consumption in different sectors with economic growth. The study uses annual time series data of Pakistan from 1972 to 2016 and applies ARDL bound test for cointegration, while Granger causality test is used for short run causality. Results showed that oil consumption in industrial and transport sector, gas consumption in fertilizer and power sector, and electricity consumption in industrial sector have positive and significant impact on economic growth in the long run. However, oil consumption in agricultural and power sector, coal consumption in power and brick kilns sector, gas consumption in cement sector, and electricity consumption in agricultural sector have negative and significant impact on economic growth. However, no causality exists between oil consumption and economic growth, while unidirectional causality exists from economic growth to coal consumption in brick kilns sector, gas consumption in industrial sector, and electricity consumption in agricultural sector in the short run. For sustainable energy supply, reduce the consumption of oil and coal to indigenously available resources, however, for sustainable economic growth, encourage industrial sector to use electricity, while fertilizer and power sector to use gas.

Keywords: Energy Consumption, Economic Growth, Disaggregate, Sectoral, ARDL, Pakistan
JEL Classifications: C32, O13, Q43

1. INTRODUCTION

Energy has been considered as a key factor of production in addition to capital, labor, human capital and technology. Energy plays an important role in the economic growth of any country. Efficient use of energy may lead to higher economic growth, while inefficient usage can decrease the economic growth of a country. Literature shows mix result about the direction of causality between energy consumption and economic growth. If there is unidirectional causality from energy consumption to economic growth it means that country is energy dependent and only increase in energy can boost economic growth and known as growth hypothesis (Saatci and Dumrul, 2013). If there is bidirectional causality between them then it implies that both variables can affect each other and serves as complements and known as feedback hypothesis (Apergis and Payne, 2009). If there is no causality exist between them it is called as neutrality hypothesis (Cheng, 1999). If causality runs from economic growth to energy consumption it means that energy consumption increased in response to increase in economic growth and termed as conservation hypothesis (Lise and Montfort, 2007).

Since 2006, Pakistan is facing severe energy crisis. The major reasons of energy crises are inefficiency of capacity addition, limited research resources, ineffective use of hydro and coal, inefficient consumption of renewable and non-renewable energy resources, which resulted in demand supply gap and led to load-shedding of electricity and gas. On average, the shortfall of electricity supply was around 5000 megawatt (MW), while it increased up to 7000 MW in July 2014. Out of 67 million tons of oil equivalent of total primary energy mix for 2013-2014, 46.4% share was of natural gas, 35% of oil, 11.4% of hydro, 5.4% of coal and 2% of nuclear including imported energy (Pakistan Economic Survey, 2014-2015).

There has been an extensive literature on the relationship between energy consumption and economic growth. The literature on the energy consumption and economic growth can be divided into two streams and these streams can be further divided into three strands i.e. unidirectional causality, bidirectional causality and combination of unidirectional, bidirectional and no causality between energy consumption and economic growth. The first stream found significant relationship between energy consumption and economic growth. Literature showed unidirectional causality (Siddiqui, 2004; Bartleet and Gounder, 2010; Saatci and Dumrul, 2013), bidirectional causality (Narayan and Smyth, 2008; Apergis and Payne, 2009; Hou, 2009), and mixed results that there is both unidirectional and bidirectional causality between energy consumption and economic growth (Asafu-Adjaye, 2000; Oh and Lee, 2004; Wolde-Rufael, 2009). The second stream analyzed the relationship between economic growth and disaggregate energy consumption i.e. coal, electricity, oil and gas. Literature showed unidirectional relationship (Halicioglu, 2007; Khan and Ahmad, 2008; Pempetzoglou, 2014;), as well as bidirectional relationship (Zachariadis and Pashourtidou, 2007; Cheng-Lang et al., 2010; Apergis and Payne, 2011), while few studies showed both bidirectional and unidirectional relationships (Abid and Mraihi, 2015; Furuoka, 2015) and the combination of unidirectional, bidirectional and no causality (Wolde-Rufael, 2006; Yoo and Kwak, 2010; Chaudhry et al., 2012).

In sum, previous literature provided mix results for the direction of the causality between disaggregate energy consumption and economic growth. However, there is limited work on the relationship between economic growth and disaggregate energy consumption in different sector of the economy in Pakistan. A trade-off is required between rapid economic growth today and growth in the future for sustainable economic growth. Energy, plays a critical role in today's rapid economic growth at the cost of non-renewable energy resources. e.g. oil, coal, and gas. The objective of this study is to analyze the relationship between energy consumption at disaggregate level i.e. oil, coal, gas and electricity consumption in different sectors i.e. commercial, agricultural, industrial, power, transport and etc. with economic growth in Pakistan. This study is useful for policy makers and individuals to make decisions regarding the consumption of energy in different sectors of the economy with sustainable economic growth.

The structure of the study is as follows. Section 2 discussed the literature review. Section 3 described the model, methodology and data. Results of long run, short run, and causality are presented in section 4. Conclusion and policy recommendations are discussed in section 5.

2. LITERATURE REVIEW

2.1. Literature on Energy Consumption and Economic Growth

Cheng (1999) examined the causality between energy consumption, capital, labor and economic growth in India from 1952 to 1995. The study found no causal relationship between energy consumption and economic growth. The study concluded that key ingredient of economic growth in India is capital accumulation. Asafu-Adjaye (2000) analyzed the association of energy consumption with income in India, Indonesia, Philippines and Thailand. The time period for India and Indonesia ranges from 1973 to 1995, while for Thailand and the Philippines the time span ranges from 1971 to 1995. Study found that unidirectional causality runs from energy towards income in India and Indonesia, while bidirectional causality exists between energy and income in Thailand and the Philippines.

Oh and Lee (2004) analyzed the causal relationship by applying multivariate model between energy consumption and economic growth in Korea from 1970 to 1999. The results showed that in long run, energy and GDP have bidirectional causality, while in the short run unidirectional causality runs from energy towards GDP. Siddiqui (2004) examined causality between economic growth and energy use in Pakistan from 1970 to 2003. The results showed unidirectional causality between energy use and economic growth. The study concluded that energy is an important element of economic growth in Pakistan. Narayan and Smyth (2008) investigated the relationship between energy consumption and real GDP in G7 countries from 1972 to 2002 and applied panel cointegration. They found that bidirectional causality exists between real GDP, capital formation and energy consumption in the selected countries.

Apergis and Payne (2009) analyzed the relationship between energy consumption with economic growth in eleven countries of the Commonwealth of Independent States from 1991 to 2005. Results supported the feedback hypothesis between energy consumption and economic growth. Hou (2009) investigated the causal link between energy consumption and economic growth in China from 1953 to 2006. The study found bidirectional causality between economic growth and energy consumption. Wolde-Rufael (2009) analyzed the causality between energy consumption and economic growth for seventeen African countries from 1971 to 2004. The results showed that unidirectional causality exists from energy consumption to economic growth in some countries, while in some other countries unidirectional causality exists from economic growth to energy consumption.

Bartleet and Gounder (2010) analyzed the energy usage and economic growth nexus in New Zealand from 1960 to 2004. They found that unidirectional causality exists from real GDP to energy consumption. Saatci and Dumrul (2013) examined the causal relation between energy consumption and economic growth with structural breaks in Turkey from 1960 to 2008. The results showed positive relation between energy consumption and economic growth. They concluded that over the years, the relationship between oil consumption and economic growth increased, which suggest energy dependence of the economy has increased. Ahmed et al. (2015) analyzed the relationship between energy consumption and economic growth in Pakistan from 1971 to 2011. They found that unidirectional causality exists from economic growth to energy consumption. Arshad et al. (2016) analyzed the impact of energy consumption on economic growth in Pakistan from 1991 to 2011. They found that energy prices have positive relation with economic growth through its impact on real interest rate and government consumption, while it negatively effects the output growth through investment, stock prices, real exchange rate and unemployment.

Mirza and Kanwal (2017) examined the causality between economic growth, energy consumption and CO_2 emission in Pakistan. They found that bidirectional causality exists between energy consumption, economic growth and the CO_2 emissions. Court (2018) reformulated the thermo-evolutionary perspective to analyze the interaction among energy, economic growth and technological change. Study found that energy plays a crucial role in human history to attain economic development as well as technological change. Ahmad et al. (2020) analyzed the dynamic causal interactions among pollutant emissions, energy investment, and economic growth in thirty Chinese provinces from 2005 to 2014. They found that bilateral causality exists among energy investment and economic growth in all the provinces of China.

2.2. Literature on Disaggregate Energy Consumption and Economic Growth

Wolde-Rufael (2006) examined the long run and causal relationship between electricity consumption per capita and real GDP per capita for 17 African countries from 1971 to 2001. The results of the study showed that unidirectional causality exists from GDP per capita to electricity consumption per capita in six countries, while in other three countries unidirectional causality exists from electricity consumption per capita to GDP per capita. Halicioglu (2007) analyzed the income and price elasticities of the residential energy consumption both in the short and long run in Turkey from 1968 to 2005. The results showed that in the long run causality runs from income, price and urbanization to residential energy. Zachariadis and Pashourtidou (2007) examined the electricity use in the residential and the services sectors of Cyprus with income, prices and weather from 1960 to 2004. They found bidirectional causality between residential electricity consumption and private income.

Khan and Ahmad (2008) analyzed the disaggregate energy i.e. petroleum, gas, electricity and coal consumption with real GDP and domestic price level for Pakistan from 1972 to 2007. They found unidirectional causality from real income and domestic price level to coal demand, while no causality exist between coal consumption, domestic price level and real GDP in the short-run. Cheng-Lang et al. (2010) investigated the linear and nonlinear causality between total electricity consumption and real GDP in Taiwan from 1982 to 2008. The results of the linear causality showed bidirectional causality among total electricity consumption, industrial sector consumption and real GDP, while neutrality among real GDP and residential sector consumption. Nonlinear causality showed bidirectional causality between total electricity consumption and real GDP, while unidirectional causality among residential sector consumption and real GDP. Yoo and Kwak (2010) examined the causal relationship between electricity consumption and economic growth in seven South American countries from 1975 to 2006. They found that causality is moving from electricity consumption to economic growth in five countries, bidirectional causality in one county, while no causal relation in one country. They concluded that high level of electricity consumption results in higher economic growth.

Apergis and Payne (2011) investigated the relationship between renewable and non-renewable energy consumption and economic growth for developed and developing countries from 1990 to 2007. They found that bidirectional causality exists between renewable and non-renewable energy consumption and economic growth both in short and long run. Chaudhry et al. (2012) investigated the relationship between disaggregate energy consumption and economic growth in Pakistan from 1972 to 2012. The results of the study showed that unidirectional causality exists from electricity consumption, oil consumption and gas consumption to economic growth, while bidirectional causality exists between economic growth and coal consumption. Shahbaz et al. (2013) analyzed the relationship between economic growth and natural gas consumption in Pakistan. They found that long run relationship exists between the variables, while natural gas consumption, capital, labor and exports have positive and significant relation with economic growth in Pakistan. Abid and Mraihi (2015) analyzed the causality between energy consumption and GDP in Tunisia at aggregate and disaggregate level from 1980 to 2012. They found that unidirectional causality exists from disaggregate energy consumption to economic growth, while bidirectional causality exists between economic growth and aggregate energy consumption.

Pempetzoglou (2014) examined the linear and nonlinear causality between electricity consumption and economic growth in Turkey from 1945 to 2006. The study found unidirectional nonlinear causality at aggregate level between income and electricity consumption, while at disaggregate level unidirectional linear causality from economic growth towards residential, commercial and street illumination electricity consumption. Furuoka (2015) examined long run relation and causality between electricity consumption and economic development in 12 Asian countries from 1971 to 2011. The study found that unidirectional causality exists from electricity consumption to economic development in South Asian countries, while unidirectional causality exists from economic development to electricity consumption in East Asian countries. Shahbaz et al. (2015) examined the relationship between renewable energy consumption and economic growth in Pakistan from 1972Q1 to 2011Q4. They found that long run relationship exists between renewable energy consumption and economic growth, while energy consumption, capital, and labor have positive relation with economic growth. Lindenberger et al. (2017) analyzed the economic growth in USA and Germany through two production functions from 1960 to 2013. They found that energy plays the most significant contribution on economic growth, while technology plays the minor contribution on economic growth.

3. MODEL, METHODOLOGY AND DATA

The study follows the neo-classical growth model to examine the effect of energy consumption on economic growth. Following Moroney (1992), Siddiqui (2004) and Yuan et al. (2008), the model assumes the production function of the following form:

$$Y_t = AK_t^{\alpha} L_t^{\beta} H_t^{\gamma} E_t^{\delta} \quad (1)$$

Where, Y_t is GDP, A is technology, K_t is capital, L_t is labor force, H_t is human capital, E_t is energy, α,β,γ and δ are the elasticities of capital, labor, human capital and energy respectively.

Following Halicioglu (2007), Zachariadis and Pashourtidou (2007), Cheng-Lang et al. (2010), Pempetzoglou (2014), and Abid and Mraihi (2015) this study disaggregate the energy into oil (OC), coal (CC), gas (GC) and electricity (EC) as:

$$Y_t = AK_t^{\alpha} L_t^{\beta} H_t^{\gamma} OC_t^{\delta} \quad (2)$$

$$Y_t = AK_t^{\alpha} L_t^{\beta} H_t^{\gamma} CC_t^{\eta} \quad (3)$$

$$Y_t = AK_t^{\alpha} L_t^{\beta} H_t^{\gamma} GC_t^{\theta} \quad (4)$$

$$Y_t = AK_t^{\alpha} L_t^{\beta} H_t^{\gamma} EC_t^{\varphi} \quad (5)$$

Each model of oil, coal, gas and electricity is further divided into two econometric models, one for total consumption and other for sectoral consumption. The study estimates eight econometric models. Model-I and model-II shows the relationship between total oil consumption and sectoral oil consumption with economic growth respectively. Followings are the econometric models for oil consumption:

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \delta \ln OC_t + \varepsilon_t \quad (6)$$

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \delta_1 \ln IOC_t + \delta_2 \ln AOC_t + \delta_3 \ln TOC_t + \delta_4 \ln POC_t + \varepsilon_t \quad (7)$$

Where, Y_t is GDP, K_t is capital, L_t is labor, H_t is human capital, OC_t is total oil consumption, IOC_t is oil consumption in industrial sector, AOC_t is oil consumption in agricultural sector, TOC_t is oil consumption in transport sector, POC_t is the oil consumption in power sector, and ε_t is the error term.

Model-III and model-IV shows the relationship between total coal consumption and sectoral coal consumption with economic growth respectively. Followings are the econometric models for coal consumption:

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \eta \ln CC_t + \varepsilon_t \quad (8)$$

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \eta_1 \ln PCC_t + \eta_2 \ln BKCC_t + \varepsilon_t \quad (9)$$

Where, Y_t is GDP, K_t is capital, L_t is labor, H_t is human capital, CC_t is total coal consumption, PCC_t is coal consumption in power sector, $BKCC_t$ is the coal consumption in brick kilns sector, and ε_t is the error term.

Model-V and model-VI shows the relationship between total gas consumption and sectoral gas consumption with economic growth respectively. Followings are the econometric models for gas consumption:

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \theta \ln GC_t + \varepsilon_t \quad (10)$$

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \theta_1 \ln CoGC_t + \theta_2 \ln CeGC_t + \theta_3 \ln FGC_t + \theta_4 \ln PGC_t + \theta_5 \ln IGC_t + \varepsilon_t \quad (11)$$

Where, Y_t is GDP, K_t is capital, L_t is labor, H_t is human capital, GC_t is total gas consumption, $CoGC_t$ is gas consumption in commercial sector, $CeGC_t$ is gas consumption in cement sector, FGC_t is gas consumption in fertilizer sector, PGC_t is gas consumption in power sector, IGC_t is gas consumption in industrial sector, and ε_t is the error term.

Model-VII and model-VIII shows the relationship between total electricity consumption and sectoral electricity consumption with economic growth respectively. Followings are the econometric models for electricity consumption:

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \varphi \ln EC_t + \varepsilon_t \quad (12)$$

$$\ln Y_t = \ln A + \alpha \ln K_t + \beta \ln L_t + \gamma \ln H_t + \varphi_1 \ln CoEC_t + \varphi_2 \ln IEC_t + \varphi \ln AEC_t + \varepsilon_t \quad (13)$$

Where, Y_t is GDP, K_t is capital, L_t is labor, H_t is human capital, EC_t is total electricity consumption, $CoEC_t$ is electricity consumption in commercial sector, IEC_t is electricity consumption in industrial sector, AEC_t is electricity consumption in agricultural sector, and ε_t is the error term.

The study conducts time series analysis in which the most important step is to check stationarity of the series to avoid spurious regression and misleading results. The study applies Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests. Dickey and Fuller (1981) presented the Dickey-Fuller unit root test in which they assume that the error terms are uncorrelated. But in order to address the situation when error terms are correlated, they presented ADF test by adding the lags of the dependent variable on the right hand side. Phillips and Perron (1988) dealt with serial correlation problem by proposing nonparametric statistical methods without adding the lag of the dependent variable.

There are various techniques that are used to check the co-integration between the variables (Engle and Granger, 1987; Johansen and Juselius, 1990; Johansen, 1995) but it is essential for these techniques that the variable should be of same order. However, to avoid these problems, when the variables are mixture of I(0) and I(1) there is another technique of cointegration introduced by Pesaran et al. (2001) which is known as "Autoregressive Distributive Lag (ARDL)." There are two assumptions of ARDL bound testing approach to cointegration i.e. regressand must be integrated of order I(1) and none of the variable is integrated of order I(2). ARDL bound testing approach is better than other techniques due to following reasons: firstly, this technique does not require pre testing of the variables i.e. regressors are purely I(0) or I(1) or mutually integrated, secondly, error correction model (ECM) is obtained from ARDL by a simple linear transformation and error correction term (ECT) integrate short run adjustments with long run.

Specification of ARDL model:

$$\Delta \ln Y_t = C + \sum_{i=1}^{p} \alpha_i \Delta \ln Y_{t-i} + \sum_{i=1}^{p} \beta_i \Delta \ln X_{t-i} + \varphi_1 \ln Y_{t-1} + +\varphi_2 \ln X_{t-1} + \varepsilon_t \quad (14)$$

Where, Δ shows the first difference of the variables, α and β represent the short run dynamics, ϕ_1 and ϕ_2 are long run coefficient which shows marginal change in dependent variable due to change in explanatory variables. In order to test the cointegration, the following null hypothesis is tested:

H_0: $\phi_1 = \phi_2 = 0$ (There is no co-integration)

H_1: $\phi_1 = \phi_2 \neq 0$

In ARDL bound test the value of F-statistics is compared with upper and lower bounds. If the value is greater than upper bound then it confirms the existence of co-integration among the variables by rejecting the null hypothesis and if the value of F-statistics fall below the lower bound then there is no co-integration but if the value falls between the upper and lower bound then the results are inconclusive. The strength of the model is tested by conducting diagnostics tests. Breusch-Godfrey test is used to check the residuals for serial correlation, Breusch-Pagan test for heteroscedasticity, and Ramsey Reset Test for functional misspecification.

To estimate the short run dynamics, it is necessary to transform the ARDL model into error correction representation. Error correction term (ECT) is the rate of adjustment which indicates that how quickly variables adjust towards equilibrium and its negative sign represents the convergence in the short run. This term should be negative and statistically significant to establish the long run relationship among the variables. The ARDL bound test confirms the existence or absence of the long run relationship among the variables but it does not provide the direction of causality. For this purpose Granger causality test is used to determine the direction of causality. Granger (1988) stated that within the framework of the ECM, causal relations among variables can be examined. The individual coefficients of the lagged terms captured the short run dynamics, while the error correction term contains the information of long run causality. So, to examine the relationship between variables, the study used VAR framework as follows:

$$\Delta \ln Y_t = \alpha_0 + \sum_{i=1}^{p} \alpha_{1i} \Delta \ln Y_{t-i} + \sum_{i=1}^{p} \alpha_{2i} \Delta \ln X_{t-i} + \varepsilon_t \quad (15)$$

$$\Delta \ln X_t = \beta_0 + \sum_{i=1}^{p} \beta_{1i} \Delta \ln X_{t-i} + \sum_{i=1}^{p} \beta_{2i} \Delta \ln Y_{t-i} + \varepsilon_t \quad (16)$$

The study uses annual time series data of Pakistan from 1972 to 2016. Data for real GDP, fixed capital formation, labor force, human capital proxy by total enrollment at middle level is collected from Pakistan Economic Survey (various issues). The data for total and sectoral consumption of oil, coal, gas and electricity is also taken from Pakistan Economic Survey (various issues). The detailed descriptions of the variables are given in Appendix A.

The data of real capital stock is constructed by using gross fixed capital formation, average rate of depreciation is supposed to be 5% (Siddiqui, 2004; Munir and Arshad, 2018). Real capital stock series is calculated by following formula:

$$K_t = (1-\mu) K_{t-1} + I_t \quad (17)$$

Where, K_t is real capital stock in time t, μ is rate of depreciation, I_t is gross fixed capital formation in year t.

In equation (15) "μ" is rate of depreciation and supposed to be constant. While, initial capital stock is calculated following Schclarek (2004) as:

$$K_0 = [I_{t-1} / (\mu + AGI] \quad (18)$$

Where, I_{t-1} is gross fixed capital formation in previous year, AGI is average growth rate of I_t.

4. RESULTS

Augmented Dickey Fuller (ADF) and Phillips-Perron (PP) unit root tests are applied to check the order of integration of the variables. The result of the unit root test shows that the dependent variable (LnY) is I(1), while the explanatory variables (capital, labor, human capital, total and sectoral consumption of oil, coal, gas and electricity) are mixture of I(1) and I(0). Results of the ADF test have been verified by PP unit root test and reported in Table 1.

In order to check the long run relationship between variables the study has applied ARDL bound test for cointegration. ARDL bound test is applied with Schwarz information criterion (SIC) for lag selection and the results are presented in Table 2. After applying bound test, F-statistics is compared with the upper and lower bound values as suggested by Pesaran et al. (2001). The values of F-statistics fall above the upper bound at 1% significance level, which means that null hypothesis of no cointegration is rejected in all the models. After establishing that variables are cointegrated, diagnostic tests are applied for serial correlation (Breusch-Godfrey serial correlation LM test), heteroscedasticity (Breusch-Pagan test) and model specification error (Ramsay RESET test). The results show that ARDL models are not suffering from serial correlation, heteroscedasticity and specification error.

Table 3 reports the result of long run coefficients in panel A. In both the models of oil consumption, the parameter of capital, labor force and human capital are significant and positively related with economic growth. The coefficient of total oil consumption in model-I has negative and significant impact on economic growth. The negative impact of total oil consumption in Pakistan is due to its high volume of imports. Higher import prices of oil have adverse effect on economic growth and stability. It is necessary that Pakistan should shift the dependency of its production from expensive oil imports to indigenously available alternative fuel i.e. hydro, gas, and solar in order to reduce import burden and consequently current account balance. Chaudhry et al. (2012) also found negative impact of oil consumption on economic growth in Pakistan. However, the sectoral oil consumption model-II shows that oil consumption in industrial and transport sector have positive and significant impact on economic growth. On the other hand, oil consumption in agricultural and power sector have negative and significant effect on economic growth. In model-III of total coal consumption the coefficient of capital stock is positive but insignificant, while labor force and human capital have positive and significant impact on economic growth. The total coal consumption has positive and insignificant effect on economic growth. Sectoral coal consumption model-IV shows that capital stock and labor force have positive and significant impact, while human capital has positive and insignificant effect on economic growth. However, the coefficients of coal consumption in power and brick kilns sector have negative and significant effect on economic growth. It implies that an increase in the consumption of coal in power and brick kilns sectors reduce economic growth.

Total gas consumption model-V shows that capital stock has negative and insignificant, while labor force and human capital

Table 1: Results of ADF and PP unit root tests

Variables	Augmented Dickey Fuller (ADF)		Phillips-Perron (PP)		Order of integration	
	At level	At 1st difference	At level	At 1st difference	ADF	PP
LnY	−2.4529	−4.6040***	−2.2257	−4.6670***	I (1)	I (1)
LnK	−11.9167***	----	−10.2456***	----	I (0)	I (0)
LnLF	−1.8913	−5.9198***	−2.0126	−5.9201***	I (1)	I (1)
LnH	5.7118	−6.1380***	5.7118	−6.1453***	I (1)	I (1)
LnOC	−1.8950	2.9232**	−1.7775	5.7708***	I (1)	I (0)
LnICO	0.9524	−4.2074***	1.0391	−4.1940***	I (1)	I (1)
LnACO	−1.2650	−5.3709***	−1.2221	−5.3481***	I (1)	I (1)
LnTCO	−3.5806**	----	−4.4674***	----	I (0)	I (0)
LnPCO	0.8887	−4.4282***	1.2304	−4.4123***	I (1)	I (1)
LnCC	−3.7211**	----	−2.6173	−7.2655***	I (0)	I (1)
LnPCC	−0.0892	−10.6627***	−3.1769	−10.7777***	I (1)	I (1)
LnBKCC	0.9834	−7.3393***	−1.6181	−7.2841***	I (1)	I (1)
LnGC	−3.1409**	----	5.0839	−4.5658***	I (1)	I (1)
LnCoCG	−5.7084***	----	−4.4068***	----	I (0)	I (0)
LnCeCG	−1.8331	−4.6355***	−1.5893	−4.6358***	I (1)	I (1)
LnFCG	−2.2965	−8.1609***	2.7958	−7.9453***	I (1)	I (1)
LnPCG	−3.2457	−4.8902***	−1.5908	−4.8854***	I (1)	I (1)
LnICG	−2.4403	−2.1448**	−1.5601	−3.5043**	I (1)	I (1)
LnEC	−3.5163**	----	−2.9479**	----	I (0)	I (0)
LnCoCE	−1.7897	−6.9018***	−2.0276	−6.8823***	I (1)	I (1)
LnICE	2.4832	−3.5534***	−1.1920	−3.5613**	I (1)	I (1)
LnACE	−2.0194	−6.2375***	−2.3099	−6.2385***	I (1)	I (1)

***, **, *Shows significance at 1%, 5% and 10% respectively

Table 2: Bound test for total and sectoral oil, coal, gas and electricity consumption

Dependent variable: LnY	F-statistics	1% critical values bound test		Cointegration exist
Model		I (0)	I (1)	
Model-I: Total Oil Consumption $F_{(LnY \vert LnK.\ LnF,\ LnH,\ LnOC)}$ (1, 0, 4, 0, 2)*	12.3488	4.4	5.72	Yes
Model-II: Sectoral Oil Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnIOC,\ LnAOC,\ LnTOC,\ LnPOC)}$ (6, 3, 3, 3, 3, 2, 1, 3)*	5.7693	2.96	4.26	Yes
Model-III: Total Coal Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnCC)}$ (3, 2, 3, 1, 1)*	5.3651	3.74	5.06	Yes
Model-IV: Sectoral Coal Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnPCC,\ LnBKCC)}$ (1, 2, 0, 2, 0,3)*	5.7029	3.41	4.68	Yes
Model-V: Total Gas Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnGC)}$ (1, 2, 4, 2, 0)*	5.1313	3.74	5.06	Yes
Model-VI: Sectoral Gas Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnCoGC,\ LnCeGC,\ LnFGC,\ LnPGC,\ LnIGC)}$ (1, 0, 0, 0, 0, 1, 0, 0, 1)*	4.2589	2.79	4.1	Yes
Model-VII: Total Electricity Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnEC)}$ (6, 3, 3, 5, 5)*	7.7741	3.74	5.06	Yes
Model-VIII: Sectoral Electricity Consumption $F_{(LnY \vert LnK.\ LnLF,\ LnH,\ LnGoEC,\ LnIEC,\ LnAEC)}$ (2, 3, 3, 3, 3, 3, 3)*	6.8337	3.15	4.43	Yes

*The model is not suffering from serial correlation, heteroscedasticity and specification error.

Table 3: Long run and short run dynamic of total and sectoral oil, coal, gas, and electricity consumption

Variables	Oil consumption		Coal consumption		Gas consumption		Electricity consumption	
	Model-I total	Model-II sectoral	Model-III total	Model-IV sectoral	Model-V total	Model-VI sectoral	Model-VII total	Model-VIII sectoral
Panel A: Long run								
LnK	0.5095***	0.8815***	0.2370*	0.8676***	−0.0377	−0.0704	0.6780***	0.0259
	(0.0770)	(0.1023)	(0.1397)	(0.1813)	(0.1826)	(0.0580)	(0.1566)	(0.1202)
LnLF	0.5496***	0.6839***	0.8342***	0.3410*	0.5639***	0.3415	0.7435***	1.0174***
	(0.0932)	(0.0909)	(0.0958)	(0.1961)	(0.1226)	(0.2233)	(0.0277)	(0.1214)
LnH	0.4147***	−0.1579*	0.1975**	0.1521	0.2162**	0.2354***	0.2422***	0.0500
	(0.0643)	(0.0780)	(0.0880)	(0.1130)	(0.1020)	(0.0650)	(0.0690)	(0.0906)
LnOC	−0.4100***	----	----	----	----	----	----	----
	(0.0956)							
LnIOC	----	0.0537**	----	----	----	----	----	----
		(0.0181)						
LnAOC	----	−0.0336*	----	----	----	----	----	----
		(0.0149)						
LnTOC	----	0.0084	----	----	----	----	----	----
		(0.0623)						
LnPOC	----	−0.0450**	----	----	----	----	----	----
		(0.0126)						
LnCC	----	----	0.0431	----	----	----	----	----
			(0.0476)					
LnPCC	----	----	----	−0.0220**	----	----	----	----
				(0.0098)				
LnBKCC	----	----	----	−0.4400**	----	----	----	----
				(0.1600)				
LnGC	----	----	----	----	0.3389***	----	----	----
					(0.1101)			
LnCoGC	----	----	----	----	----	0.1676	----	----
						(0.1479)		
LnCeGC	----	----	----	----	----	–0.0501***	----	----
						(0.0110)		
LnFGC	----	----	----	----	----	0.1304***	----	----
						(0.0323)		
LnPGC	----	----	----	----	----	0.2291***	----	----
						(0.0518)		
LnIGC	----	----	----	----	----	–0.0084	----	----
						(0.0743)		
LnEC	----	----	----	----	----	----	–0.1628	----
							(0.1233)	
LnCoEC	----	----	----	----	----	----	----	–0.1040
								(0.0589)
LnIEC	----	----	----	----	----	----	----	0.4743***
								(0.1352)
LnAEC	----	----	----	----	----	----	----	–0.1422**
								(0.0497)
C	15.5271***	1.6677	17.2006***	4.3494	22.2556***	22.8387***	5.8460	22.0378***
	(0.8052)	(2.1968)	(3.5115)	(3.6947)	(4.0127)	(1.1068)	(3.7146)	(2.8983)
Panel B: Short run ECM								
ECT(–1)	–0.3291***	–0.9504***	–0.5090***	–0.3407***	–0.4151***	–0.4842***	–0.9385**	–0.8157***
	(0.0713)	(0.0973)	(0.0868	(0.1226)	(0.1482)	(0.1030)	(0.2540)	(0.1945)

Dependent variable LnY

Standard errors are in parenthesis. ***, **, *Shows significance at 1%, 5% and 10% respectively.

have positive and significant impact on economic growth. The coefficient of total gas consumption has positive and significant impact on economic growth. Being a country with abundant natural gas resources, an increase in gas consumption increases economic growth. However, the sectoral gas consumption model-VI shows that gas consumption in power and fertilizer sector have positive and significant effect on economic growth, while gas consumption in cement sector has negative and significant effect on economic growth. Gas consumption in commercial sector has positive, while in industrial sector has negative and insignificant effect on economic growth. Pakistan has the most developed distribution network of gas in the region but on the account of its increased demand the gap between the demand and supply is widening which is badly affecting industrial sector. The results of total electricity consumption model-VII show that capital stock, labor force and human capital have positive and significant effect on economic growth, while total electricity consumption has negative and insignificant effect on economic growth. The sectoral electricity consumption model-VIII shows that electricity consumption in industrial sector has positive and significant impact on economic growth, while the impact of electricity consumption in agricultural sector is negative and significant. Electricity consumption in commercial sector has negative and insignificant effect on economic growth. The negative impact of electricity is due to non-availability of energy to the commercial sector due to which production has decreased. Pakistan has to use alternative method of energy production to produce the electricity so that the production could be increased and country can move towards sustainable economic growth.

To estimate the short run dynamics, it is necessary to transform the ARDL model into error correction model (ECM). Error correction term (ECT) is the rate of adjustment that indicates how quickly variables adjust towards equilibrium and its negative sign represents the convergence in the short run. Table 3 reports the result of short run error correction term (ECT) in panel B for all the models. The estimated coefficient of ECT is negative and significant in all the models.

The ARDL bound test confirms the existence or absence of the long run relationship among the variables but it does not provide the direction of causality. For this purpose, Granger causality test is used to determine the direction of causality. Table 4 reports the result of causality between total and sectoral consumption of oil, coal, gas and electricity consumption and economic growth. The results show that no causality exists between economic growth and oil consumption at total and sectoral level. These results represent the existence of neutrality hypothesis between oil consumption and economic growth in Pakistan (Cheng, 1999). In case of coal consumption, unidirectional causality exists from economic

Table 4: Results of causality for total and sectoral oil, coal, gas and electricity consumption

Model	Chi-square statistics	Causality
Total oil consumption		
Economic Growth → Total Oil Consumption	2.5709	No
Total Oil Consumption → Economic Growth	1.9458	No
Sectoral oil consumption		
Economic Growth → Oil Consumption in Industrial Sector	1.0033	No
Oil Consumption in Industrial Sector → Economic Growth	0.4107	No
Economic Growth → Oil Consumption in Agricultural Sector	3.1173	No
Oil Consumption in Agricultural Sector → Economic Growth	0.2205	No
Economic Growth → Oil Consumption in Transport Sector	1.8646	No
Oil Consumption in Transport Sector → Economic Growth	2.2737	No
Economic Growth → Oil Consumption in Power Sector	1.1096	No
Oil Consumption in Power Sector → Economic Growth	1.1814	No
Total coal consumption		
Economic Growth → Total Coal Consumption	6.8725**	Yes
Total Coal Consumption → Economic Growth	1.7544	No
Sectoral coal consumption		
Economic Growth → Coal Consumption in Power Sector	1.5391	No
Coal Consumption in Power Sector → Economic Growth	3.9973	No
Economic Growth → Coal Consumption in Brick Kilns Sector	16.5359***	Yes
Coal Consumption in Brick Kilns Sector → Economic Growth	1.1473	No
Total gas consumption		
Economic Growth → Total Gas Consumption	4.5199	No
Total Gas Consumption → Economic Growth	0.2355	No
Sectoral gas consumption		
Economic Growth → Gas Consumption in Commercial Sector	1.4271	No
Gas Consumption in Commercial Sector → Economic Growth	0.1435	No
Economic Growth → Gas Consumption in Cement Sector	0.5567	No
Gas Consumption in Cement Sector → Economic Growth	0.6723	No
Economic Growth → Gas Consumption in Fertilizer Sector	1.2686	No
Gas Consumption in Fertilizer Sector → Economic Growth	1.4561	No
Economic Growth → Gas Consumption in Power Sector	0.6184	No
Gas Consumption in Power Sector → Economic Growth	1.5423	No
Economic Growth → Gas Consumption in Industrial Sector	6.6833**	Yes
Gas Consumption in Industrial Sector → Economic Growth	0.2896	No
Total electricity consumption		
Economic Growth → Total Electricity Consumption	16.0824***	Yes
Total Electricity Consumption → Economic Growth	0.3056	No
Sectoral electricity consumption		
Economic Growth → Electricity Consumption in Commercial Sector	3.7529	No
Electricity Consumption in Commercial Sector → Economic Growth	1.6952	No
Economic Growth → Electricity Consumption in Industrial Sector	7.9351**	Yes
Electricity Consumption in Industrial Sector → Economic Growth	3.6071	No
Economic Growth → Electricity Consumption in Agricultural Sector	8.1995**	Yes
Electricity Consumption in Agricultural Sector → Economic Growth	1.2894	No

***, **, *Shows significance at 1%, 5% and 10% respectively.

growth to total coal consumption, while in case of sectoral coal consumption unidirectional causality exists from economic growth to coal consumption in brick kilns sector. Conservation hypothesis holds in case of coal consumption and economic growth in Pakistan (Lise and Montfort, 2007).

No causality exists between total gas consumption and economic growth which supports the neutrality hypothesis. However, unidirectional causality exists from economic growth to gas consumption in industrial sector which supports the conservation hypothesis. In case of electricity, unidirectional causality exists from economic growth to total electricity consumption, while in case of sectoral electricity consumption unidirectional causality exists from economic growth to electricity consumption in agricultural sector. These results show that conservation hypothesis holds in case of economic growth and electricity consumption.

5. CONCLUSION

Energy has been considered as a key factor of production in addition to capital, labor, human capital and technology. Efficient use of energy leads to higher economic growth. The objective of this study is to analyze the relationship between energy consumption at disaggregate level i.e. oil, coal, gas and electricity consumption in different sectors i.e. commercial, agricultural, industrial, power, transport and etc. with economic growth in Pakistan. The theoretical model used in this study is the neo-classical growth model which provide framework to analyze the relationship between economic growth and oil, coal, gas and electricity consumption. The study has used annual time series data of Pakistan from 1972 to 2016 and applied ARDL bound test for cointegration, while Granger causality test is used for short run causality.

The results of the study show that in the long run the coefficient of total oil consumption, oil consumption in agricultural and power sector have negative and significant impact on economic growth, while oil consumption in industrial and transport sector has positive and significant impact on economic growth. In short run no causality exists between oil consumption and economic growth, which supports the neutrality hypothesis. In case of coal consumption, the coefficient of total coal consumption is positive but insignificant, while coal consumption in power and brick kilns sector have negative and significant effect on economic growth in the long run. Unidirectional causality exists from economic growth to total coal consumption and coal consumption in brick kilns sector in the short run, which supports the conservation hypothesis.

Total gas consumption, gas consumption in fertilizer and power sector have positive and significant impact, while gas consumption in cement sector has negative and significant impact on economic growth in the long run. In the short run, unidirectional causality exists from economic growth to gas consumption in industrial sector, which supports the conservation hypothesis. In the long run, the coefficient of total electricity consumption is negative and insignificant. However, electricity consumption in agricultural sector has negative and significant impact, while electricity consumption in industrial sector has positive and significant impact on economic growth. Moreover, in the short run unidirectional causality exists from economic growth to total electricity consumption, and electricity consumption in agricultural sector which supports the conservation hypothesis.

In the light of the above findings, the study suggests the following recommendations: For sustainable energy supply, government has to reduce the consumption of oil and coal to indigenously available resources i.e. hydro, gas and solar. For sustainable long run economic growth, government has to encourage industrial sector to use electricity, while fertilizer and power sector to use gas.

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APPENDIX

Appendix A

Variables	Description	Sources
K	Capital (Gross fixed capital formation in constant term)	Pakistan Economic Survey
L	Labor Force (in millions)	Pakistan Economic Survey
Y	Economic Growth (Gross Domestic Product in constant terms)	Pakistan Economic Survey
H	Total enrollment at middle school used as a proxy for human capital (in thousands)	Pakistan Economic Survey
OC	Total oil consumption (in tons)	Pakistan Economic Survey
IOC	Oil consumption in industrial sector	Pakistan Economic Survey
AOC	Oil consumption in agricultural sector	Pakistan Economic Survey
TOC	Oil consumption in transport sector	Pakistan Economic Survey
POC	Oil consumption in power sector	Pakistan Economic Survey
CC	Total coal consumption (in metric tons)	Pakistan Economic Survey
PCC	Coal consumption in power sector	Pakistan Economic Survey
BKCC	Coal consumption in brick kilns sector	Pakistan Economic Survey
GC	Total gas consumption (mm cft)	Pakistan Economic Survey
CoGC	Gas consumption in commercial sector	Pakistan Economic Survey
CeGC	Gas consumption in cement sector	Pakistan Economic Survey
FGC	Gas consumption in fertilizer sector	Pakistan Economic Survey
PGC	Gas consumption in power sector	Pakistan Economic Survey
ICG	Gas consumption in industrial sector	Pakistan Economic Survey
EC	Total electricity consumption (in Gwh)	Pakistan Economic Survey
CoEC	Electricity consumption in commercial sector	Pakistan Economic Survey
IEC	Electricity consumption in industrial sector	Pakistan Economic Survey
AEC	Electricity consumption in agricultural sector	Pakistan Economic Survey