© The Pakistan Development Review
52:4 Part I (Winter 2013) pp. 493–516

Disaggregate Energy Consumption, Agricultural Output and Economic Growth in Pakistan

MUHAMMAD ZAHIR FARIDI and GHULAM MURTAZA

1. INTRODUCTION

The performance of an economy is generally measured by sustained rise in GDP growth over the period of time. The economic growth is the major goal of macroeconomics. According to neo-classical growth theory, the core factors of growth are labour and capital. In addition to these factors; technological progress, human capital development etc. are the most efficient factors of production. Development of technology and use of mechanisation in production process require energy at massive scale. So, energy has become a crucial factor of economic growth indirectly.

Energy is widely regarded as a propelling force behind any economic activity and indeed plays a vital role in enhancing production. Therefore, highly important resources of energy will enhance the technology impact manifold. Quality energy resources can act as facilitator of technology while less worthy resources can dampen the power of new technology. Ojinnaka (1998) argued that the consumption of energy tracks with the national product. Hence, the scale of energy consumption per capita is an important indicator of economic modernisation. In general countries that have higher per capita energy consumption are more developed than those with low level of consumption.

The importance of energy lies in other aspect of development—increase in foreign earnings when energy products are exported, transfer of technology in the process of exploration, production and marketing; increase in employment in energy industries; improvement of workers welfare through increase in worker's salary and wages, improvement in infrastructure and socio-economic activities in the process of energy resource exploitation. Thus in the quest for optimal development and efficient management of available energy resources, equitable allocation and efficient utilisation can put the economy on the part of sustainable growth and development. Arising from this argument, adequate supply of energy thus becomes central to the radical transformation of the nation's economy.

Muhammad Zahir Faridi, PhD <zahirfaridi@bzu.edu.pk> is Assistant Professor at Bahauddin Zakariya University, Multan, Pakistan. Ghulam Murtaza <GM.QAUI@gmail.com, ghulammurtaza_14@pide.org.pk> is Visiting Lecturer at Bahauddin Zakariya University, Multan, Pakistan.

Authors' Note: The authors gratefully acknowledge the comments and suggestions received from Mahmood Khalid, PIDE at the 29th AGM and Conference, PSDE.

The main objective of the study is to investigate the effect of disaggregate energy consumption on agricultural output and generally overall growth in Pakistan. Because agriculture is the mainstay of Pakistan economy and is basic production sector. The manufacturing sector, services sector and even communication sector have secondary position albeit their growth rates are higher in absolute terms. The growth rate of agricultural sector is very low. When structural changes have occurred, the process of mechanisation has taken place in the agricultural sector. The use of energy has increased for running the machinery like tubewells, tractors, threshers etc. Due to shortfall of energy, the output of agricultural sector has dropped.

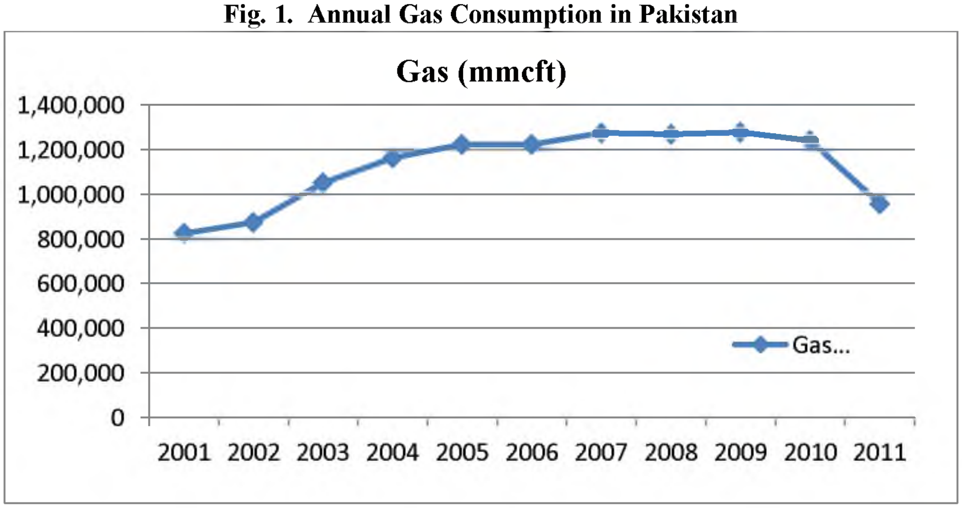
One of the interesting features of the study is that it differentiates short run and the long run effect because it has been observed that impact of energy consumption varies from short to long run for the same country. For this purpose, we have employed ARDL modelling to co-integration to find out long run and short run effect. Unit root problem of the data is handled by ADF test. The rest of the article is structured as follows. Trends and structure of energy variables are given in Section 2. Section 3 provides literature review in detail while data and methodology are given in Section 4. Empirical results and their discussion are presented in Section 5. At the end, some policy implications for energy consumption are suggested on the basis of empirical results.

2. TRENDS AND SIZE OF PAKISTAN ANNUAL ENERGY CONSUMPTION

Total energy consumption measured in oil consumption is 38.8 million tonnes in the year of 2010-11. Currently gas consumption is the leading one in total energy consumptions that is 43.2 percent of total energy consumption. Since 2005-06, Gas, electricity and coal consumption are equally utilised. Oil consumption stood at second position regarding usage as its usage is 29 percent of total energy consumption.

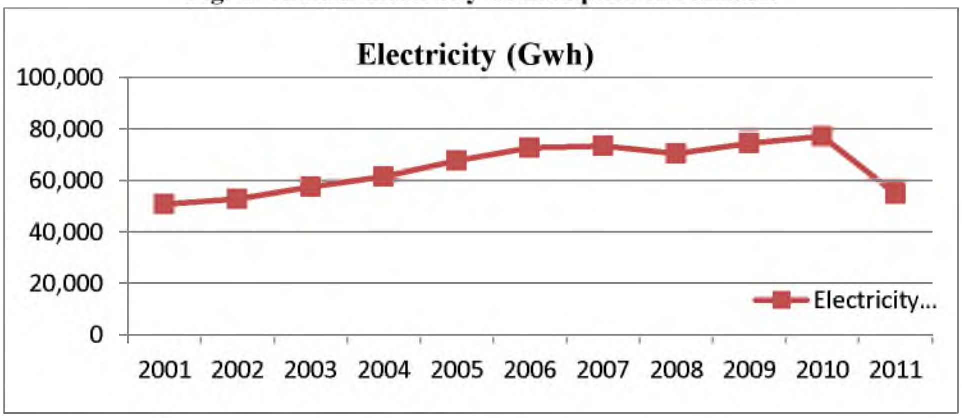
We present the trends of energy consumption at disaggregate level in Pakistan over the last decade. The Figure 1 explains the trends of annual gas consumption. While, Figure 2 and Figure 3 provide the trends of annual electricity consumption and annual oil consumption respectively.

Fig. 1. Annual Gas Consumption in Pakistan



Gas consumption share is equal to four percent of total energy consumption during 2005-06 to 20010-11. This is because of the substitution of gas for expensive energy sources. The consumption of oil in Pakistan decreased by three percent during the period 2001-2011 because of high prices of oil in the international market. Since the year 2001-02, a decreasing trend is observed in the consumption of petroleum products.

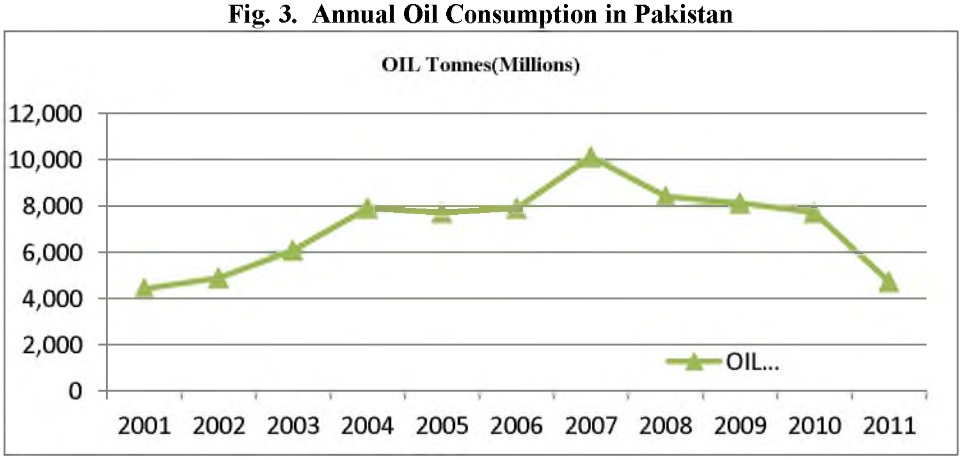
Fig. 2. Annual Electricity Consumption in Pakistan



Source: Pakistan Economic Survey (Various Issues).

Yet it is observed that there has been an increase in oil consumption from 2004-10, the overall average increase for last ten years stood at 11 percent per annum. Trends indicate that due to high volatility in the oil prices consumption intensity is shifting from oil consumption to some others sources of energy consumption. Figure 2 indicates that the trend of annual electricity consumption (in Giga Watt Hour) over the last ten years i.e., 2001-2011. Trends show that electricity consumption increased continuously till 2007 and then fell. But after the year 2010, there is sharp decline in electricity consumption. Thus, Gas, electricity and oil consumption trends indicate an annual increase at an average rate of 5.1 percent, 4.8 percent and 7.7 percent respectively.

Fig. 3. Annual Oil Consumption in Pakistan



Source: Pakistan Economic Survey (Various Issues).

3. LITERATURE REVIEW

Theoretically, neo-classical and endogenous theories both suggest that energy use and efficiency are drivers of economic growth. Though there are many studies that find a direct relationship between productivity and energy consumption in the industrialised world [see Worrell, *et al.* (2001)], evidence from the developing world remains inconclusive. Few disaggregated studies have been conducted on this issue and the studies using data aggregated at the national or economic level indicate mixed findings. Further complicating the relationship is the extent to which economic growth and energy consumption can theoretically be decoupled, a question raised by ecological economists who argue thermodynamic laws limit such division. Below is a brief review of the various theories on the relationship between energy consumption, energy efficiency and economic growth, followed by a summary of a select list of empirical studies.

By incorporating energy end-use efficiency gains into a Cobb-Douglas production function, Wei (2007) theorizes about short-term and long-term effects of increased energy efficiency beginning with the production function specification as output is a function of labour, capital and some measures of energy consumption. In the short term, energy use efficiency is found to lower the cost of non-energy goods and increase the output of non-energy goods. A 100 percent rebound effect is evident such that in the short term, energy efficiency gains have no effect on absolute energy use. In the long term, the impact on non-energy output of energy end use efficiency is positive. The long term impact of energy use efficiency on total energy use is lower than the short-term impact. Wei also finds that energy use efficiency will increase real energy price in the long term. Van Zon and Yetkiner (2003) modify the Romer model to include energy consumption of intermediates and to make them heterogeneous due to endogenous energy-saving technical change. They found out that energy-saving technical transformation can enhance economic growth. On the other hand, it may dampen economic growth with the increase in energy prices that imply that rising real energy prices consistently will cause to harm economic growth.

Embodied technical change includes improvements in energy efficiency, thus positively linking improvements in energy efficiency to economic growth. They conclude that in an environment of rising energy prices, recycling energy tax proceeds in the form of R&D is necessary for both energy efficiency growth and output growth. Sorrell (2009) pointed out that conventional and ecological economists have conflict on the issue of energy effects on economic growth. The growth models presented by Neo-classical and new Endogenous growth theories give little importance to energy consumption as a major factor of production by giving argument that it has a small share in total cost of production. Ecological economist contests their point of view by replying that over the last two centuries, energy inputs are accelerating economic growth at valuable rate.

For a steady economic growth the role of technological change is of great importance as earlier growth models have integrated technological change as an important factor for growth [Solow (1956)]. Energy and raw material besides labour and capital cause to decrease the statistical residual. Onakoya, *et al.* (2013) studied the relationship between energy consumption and Nigerian economic growth during the period of 1975 to 2010 to find out energy consumption as an important variable for production. Co-integration results provided evidence of a long run relationship between energy consumption and economic growth which was positive. Same results were also found by Paul and Bhattacharya (2004) who employed Engle–Granger technique to investigate the direction of relationship between economic growth and energy consumption for India for the period of 1950-1996. Results revealed that energy consumption has causality for energy consumption. Hondroyiannis, *et al.* (2002) followed the same results in case of Greece by using vector error-correction estimation on the data from 1960-1996. The findings of the study indicate the existence of long run relationship.

Oh and Lee (2004) did not find the significant and positive effect of energy consumption on growth in case of Korea. For Bangladesh, Mozumder and Marathe (2007) examined a positive relationship between per capita income and per capita energy consumption. The relationship between gas consumption and growth was analysed by Apergis and Payne (2010) to reveal the co-integration among labour, capital, gas consumption and economic growth. ECM model was employed to find the bidirectional causality between gas consumption and economic growth but Yang (2000) opposed this relationship as his study show the absence of long run relationship between natural gas consumption and real GDP. Same results of no relationship are also found out by Aqeel and Butt (2001).

Shahbaz and Feridun (2011) investigated the impact of electricity consumption on economic growth in Pakistan between 1971 and 2008 by using ARDL technique to identify the long run relationship between electricity consumption and economic growth. Study gives the evidence of long run relationship between electricity consumption and economic growth but inverse is not true. Alam and Butt (2001) investigation provided the evidence that structural changes also cause to change the share of various energy consumption variables. And increase in energy is because of increase in economic activity as well as structural changes.

Javid, *et al.* (2013) argued that shocks to electricity supply will have a negative impact on economic growth. Nwosa and Akinbobola (2012) and Dantama, *et al.* (2011) come to a conclusion that govt. should adopt sector specific energy policies rather the one fit-for-all policy by observing positive aggregate energy consumption and sectoral output.

For Pakistan, Kakar and Khilji (2011) explored the nature of relationship between economic growth and total energy consumption for the period 1980-2009 by using Johansen Co- integration and confirmed that energy consumption is essential for economic growth and any energy shock may affect the long-run economic development of Pakistan. Ahmad, *et al.* (2013) analysed the impact of energy consumption and economic growth in case of Pakistan employing data from 1975 to 2009. The results of ordinary least squares test show positive relation between GDP and energy consumption in Pakistan.

A number of reviews of prior work compel us to make a healthy endeavour on the concerned issues because a little attention has been given to agricultural sector regarding energy consumption relationship. We have observed in the literature review most of the studies are emphasising on the relationship between overall growth and energy, manufacturing sector growth and energy. A few studies discuss the agricultural sector growth and energy. But the present study removes a number of imperfections of previous studies such as use of energy consumption and its relationship with overall economic growth instead of growth in agricultural sector at the disaggregate level. We have used fresh data on certain variables. An appropriate technique for co-integration, model specification and proper estimation technique is employed.

4. DATA AND METHODOLOGY

The present segment consists of data and methodology used to estimate effects of disaggregates energy consumption on economic growth and Agricultural output in Pakistan. To order to analyse relationships, secondary data from year 1972-2011 are employed and Auto Regressive Distributed Lags (ARDL) technique has been used.

(a) Data Source

The data generated from *Pakistan Economic Survey* (various issues), *Handbook of Statistics of Pakistan Economy*. While, data on variables of energy consumption, have been obtained from HDIP, Ministry of Petroleum and Natural Resources. The variables about which data are collected, are RGDP (Gross Domestic Product) that is used as dependent variable while RGFCF (Real Gross Fixed Capital Formation), TELF (Total Employed Labour Force), IR (Inflation Rate), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), AGRI (Agricultural Output), TELF (Total Employed Labour Force), RAGFCF (Real Agricultural Gross Fixed Capital Formation), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), ACRDT (Agricultural Credit).

(b) Methodological Issues

The study is based on time series data. In order to examine the properties of the time series data, we first examine the stationarity of data and then decide about the appropriate technique.

(i) *Stationarity of Data*

In practice, ADF test is used to check the stationary of variables to see if all the variables are integrated of degree one. In this case, the variables can be estimated by employing error correction model because of co-integrated series. However, if all the variables are not integrated of same degree i.e. some variables are integrated at I (1) or some are at I (0) or both I(1) and I(0) then ARDL modeling approach will be employed to identify the existence of long run and short run relationships among the variables.

(ii) *Auto Regressive Distributed Lag Approach to Co-integration*

ARDL approach will be applied only on single equation. It will estimate the long run and short run parameters of model simultaneously. The estimated model obtained from the ARDL technique will be unbiased and efficient. ARDL approach to co-integration is useful for small sample Narayan (2004). Engel-Granger and Johensan technique are not reliable for small samples. ARDL gives better results in sample rather than Johesan co-integration approach. ARDL approach has a drawback because it is not necessary that all variables are of same order. The variables can be at I(0) or I(1) or combination of both, the ARDL approach can be applied. If the variables are stationary at higher order of I(1) then ARDL is not applicable. ARDL approach consists of two stages. First, the long run relationship between variables is tested using F-statistics to determine the significance of the lagged levels variables. Second, the coefficient of the long run and short run relationship will be examined.

(iii) *Bound Testing Procedure*

The bound test is based on three basic assumptions that are; first, use ARDL model after identifying the order of integration of series Pesaran, *et al*. (2001). Second, series are not bound to possess the same order of integration i.e., the regressors can be at I(0) or I(1). Third, this technique estimates better results in case of small sample size. The vector auto regression (VAR) of order *p,* for the economic growth function can be narrated as Pesaran, *et al*. (2001);

$$Z_t = \mu + \sum_{i=1}^{p} \beta_i z_{t-i} + \varepsilon_t \qquad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (1)$$

Where x_t and y_t are included in vector z_t. Economic growth (RGDP) and agricultural output (AGRI) are indicated by y_t and x_t is the vector matrix which represents a set of explanatory variables such as [*Xt = RGFCF, TELF, TOC, TEC, TGC, IR*] and [*Xt = TELF, RGFCF, TOC, TGC, TEC, ACRDT*] for Model-1 and Model-2 and *t* denotes time indicator. Vector error correction model (VECM) is given as below:

$$\Delta z_t = \mu + \alpha t + \lambda z_{t-1} + \sum_{i=1}^{p-i} \gamma_t \Delta y_{t-i} + \sum_{i=1}^{p-1} \gamma_t \Delta x_{t-i} + \varepsilon_t \qquad \ldots \quad \ldots \quad \ldots \qquad (2)$$

where Δ is the first-difference operator. The long-run multiplier matrix λ as:

$$\lambda = \begin{bmatrix} \lambda_{YY} \lambda_{YX} \\ \lambda_{XY} \lambda_{XX} \end{bmatrix}$$

The diagonal elements of the matrix are unrestricted, so the selected series can be either I(0) or I(1). If $\lambda_{YY} = 0$, then *Y* is I(1). In contrast, if $\lambda_{YY} < 0$, then *Y* is I(0).

The VECM procedures described above are imperative in the testing of at most one co-integrating vector between dependent variable y_t and a set of regressors x_t. To build up the model, study uses Pesaran, *et al.* (2001) postulation of Case V, that is, unrestricted intercepts and trends.

(c) Description of the Variables

In the present analysis, we have used the variables like employed labour force and real gross fixed capital formation as theoretical variables for growth and there are three core variables relating to energy. Two variables are used as control factors. The explanation and hypothetical relation of these variables are given below.

Real Gross Domestic Product (RGDP)

Real gross domestic product at factor cost is used as proxy for economic growth. It is assumed as GDP expands over the period of time, the economy will grow. RGDP is measured in millions rupees.

Agricultural Output (AGRI)

In order to measure the performance of agricultural sector, we have used agricultural output measured at current market prices in million rupees.

Real Gross Fixed Capital Formation (RGFCF)

We have considered real gross fixed capital formation as a proxy for capital in the present study. It is measured at market prices in million rupees.

Total Employed Labour Force (TELF)

Labour is used as a core variable in economic growth model. It is expected that labour contributes positively to economic growth. The present study uses total employed labour force as a proxy for labour. Total employed labour force is measured in millions peoples.

Total Oil Consumption (TOC)

Total oil consumption is measured in thousands of tonnes per year. It is expected that oil consumption has positive relationship with growth.

Total Gas Consumption (TGC)

It is expected that the utilisation of gas consumption cause to increase the GDP growth positively. We have used total gas consumption in million cubic feet (mmcft).

Total Electricity Consumption (TEC)

Use of electricity in production process is an important factor. Due to shortage of electricity it is expected that total electricity consumption is contributing negatively to GDP growth as well as to agriculture output. The total electricity consumption per Annam is measured in Giga Watt hour (GWh) or (10^6 Kilo Watt hour).

Agricultural Credit (ACRDT)

Agricultural credit is used as a central variable in the present analysis. The expected impact of agricultural credit on output is positive. Agricultural credit is measured in million rupees.

Inflation Rate (IR)

In order to examine the effect of general price level on economic growth, we have used consumer price index as a proxy for inflation rate. The inflation rate has negative impact on economic growth because cost of the production increases, output falls and growth is retarded.

(d) Model Specification

The current study is based on general Neo-classical Production Function;

$$Y = A\,f(L, K) \quad \ldots \quad (3)$$

Where, Y = Total output, L = Total employed labour force, K= Total stock of capital, A= Total productivity factor.

We have employed extended neo-classical growth model by incorporating energy as a productivity factor as an endogenous variable.

$$A = f(TOC, TGC, TEC) \quad \ldots \quad (4)$$

Substituting A in Equation (i), we obtained extended growth model.

$$Y = f(L, K, TOC, TGC, TEC) \quad \ldots \quad (5)$$

Based on the suggested economic techniques, we have two specified model. These specified models are given below.

Model-1. Impact of Disaggregate Energy Consumption on Economic Growth

$$\begin{aligned}\Delta(RGDP)_t = {} & \beta_0 + \sum_{i=0}^{a}\beta_{1i}\Delta(RGFCF)_{t-i} + \sum_{i=0}^{b}\beta_{2i}\Delta(TELF)_{t-i} + \sum_{i=0}^{c}\beta_{3i}\Delta(TOC)_{t-i} + \sum_{i=0}^{d}\beta_{4i}\Delta(TGC)_{t-i} \\ & + \sum_{i=0}^{e}\beta_{5i}\Delta(TEC)_{t-i}\ \sum_{i=0}^{g}\beta_{7i}\Delta(IR)_{t-i} + \beta_8(RGDP)_{t-1} + \beta_9(RGFCF)_{t-1} + \sum_{i=1}^{f}\beta_{6i}\Delta(RGDP)_{t-i} + \\ & + \beta_{10}(TELF)_{t-1} + \beta_{11}(TOC)_{t-1} + \beta_{12}(TGC)_{t-1} + \beta_{13}(TGC)_{t-1} + \beta_{14}(IR)_{t-1} + u_t \quad \cdots \quad (6)\end{aligned}$$

Where, Δ is the first-difference operator while *Ut* is a white-noise disturbance term. This model would estimate the impact of disaggregate energy consumption on economic growth in which real GDP is used as dependant variable while real gross fixed capital formation (proxy for capital), total employed labour force, total oil consumption, total gas consumption an total electricity consumption are used as independent variables.

Equation (6) also can be viewed as an ARDL of order (*a, b, c, d, e, f, g*). Equation (6) indicates that economic growth tends to be influenced and explained by its past values. The structural lags are established by using minimum Schwarz Information Criteria (SIC). In our model, we will use the lagged value of first difference dependent variable and independent variables for short run and first lagged values of dependent and independent variables for long run. So, this model is consisted of both long run and short run coefficients of variables as well. Where β_1, β_2, β_3, β_4, β_5 and β_6, β_7 are the short run coefficients of variables and β_8, β_9, β_{10}, β_{11}, β_{12} and β_{13}, β_{14} are the long run coefficients of variables and β_0 is the intercept term.

Model-2. Impact of Disaggregate Energy Consumption on Agricultural Output

The second model would capture the effect of energy consumption on agricultural output in Pakistan with the help of some explanatory variables like TELF (Total Employed Labour Force), RGFCF (Real Gross Fixed Capital Formation), TOC (Total Oil Consumption), TGC (Total Gas Consumption), TEC (Total Electricity Consumption), ACRDT (Agricultural Credit); the unrestricted ECM model for Agricultural output is as under;

$$\Delta AGRI_t = \phi_0 + \sum_{i=1}^{p} \phi_{1i}\Delta(TELF)_{t-i} + \sum_{i=0}^{q} \phi_{2i}\Delta(RGFCF)_{t-i} + \sum_{i=0}^{r} \phi_{3i}\Delta(TEC)_{t-i} + \sum_{i=0}^{s} \phi_{4i}\Delta(TGC)_{t-i}$$
$$+ \sum_{i=0}^{t} \phi_{5i}\Delta(TOC)_{t-i} + \sum_{i=0}^{u} \phi_{6i}\Delta(ACRDT)_{t-i} + \sum_{i=1}^{v} \phi_{7i}\Delta(AGRI)_{t-i} + \gamma_1(AGRI)_{t-1} + \gamma_2(TELF)_{t-1}$$
$$+ \gamma_3(RGFCF)_{t-1} + \gamma_4(TEC)_{t-1} + \gamma_5(TGC)_{t-1} + \gamma_6(TOC)_{t-1} + \gamma_7(ACRDT)_{t-1} + \mu_t \quad \cdots \quad (7)$$

Where Δ shows the first difference operator and U_t is the residual of the model.

Equation (7) also can be viewed as an ARDL of order (*p, q, r, s, t, u, v*). Where ϕ_{1i}, ϕ_{2i}, ϕ_{3i} and ϕ_{4i}, ϕ_{5i}, ϕ_{6i}, ϕ_{7i} are the short run coefficients of variables and γ_1, γ_2, γ_3, γ_4, γ_5, γ_6 and γ_7 are the long run coefficients of variables and ϕ_0 is the intercept term.

The Wald Test (F-statistics)

After regression of Equation (6) and Equation (7), the Wald test (*F*-statistic) is computed to differentiate the long-run relationship between the concerned variables. The Wald test can be carried out by imposing restrictions on the estimated long-run coefficients of real GDP, total employed labour force, real gross fixed capital formation, total oil consumption, total gas consumption, total electricity consumption and inflation rate for the Model-1 as under:

The null hypothesis is as follows;

$H_0 : \beta_8 = \beta_9 = \beta_{10} = \beta_{11} = \beta_{12} = \beta_{13} = \beta_{14} = 0$ (No long-run relationship exists)

Against the alternative hypothesis,

$H_1 : \beta_8 \neq \beta_9 \neq \beta_{10} \neq \beta_{11} \neq \beta_{12} \neq \beta_{13} \neq \beta_{14} \neq 0$ (A long-run relationship exists)

If the calculated F-statistics does not exceed lower bound value, we do not reject Null Hypothesis and it is concluded that there is no existence of long run relationship between RGDP and independent variables. On the other hand, if the calculated F-statistics exceeds the value of upper bound, the co-integration exists between RGDP and independent variables. We will apply the Wald coefficient test on all lagged explanatory and dependant variables in the model Equations (7). Our null hypothesis will be that lagged coefficient of explanatory variables are equal to zero or absent from the model. If we do not reject the null hypothesis it means long run relationships among variables do not exist.

Null and alternative hypothesis for Model-2 to apply Wald test is as follows.

H_0: $\gamma_1 = \gamma_2 = \gamma_3 = \gamma_4 = \gamma_5 = \gamma_6 = \gamma_7 = 0$ (No Cointegration Exists)
H_1: $\gamma_1 \neq \gamma_2 \neq \gamma_3 \neq \gamma_4 \neq \gamma_5 \neq \gamma_6 \neq \gamma_7 \neq 0$ (Cointegration Exists)

(d) The Time Horizons

To see the effects of explanatory variables on economic growth in case of Pakistan both in the short run and long run, we have to estimate the model which are given Equations (6) and (7) with OLS (Bound test approach to co-integration) technique and then normalise the resulting values. The ARDL model for the long run coefficient of

Model-1Equation (6) is to determine the long run effect of energy consumption on economic growth in Pakistan.

$$
\begin{aligned}
RGDP_t = {} & \eta_0 + \sum_{i=1}^{k_1} \eta_{1i}(RGDP)_{t-i} + \sum_{i=0}^{k_2} \eta_{2i}(RGFCF)_{t-i} + \sum_{i=0}^{k_3} \eta_{3i}(TELF)_{t-i} \\
& + \sum_{i=0}^{k_4} \eta_{4i}(TEC)_{t-i} + \sum_{i=0}^{k_5} \eta_{5i}(TOC)_{t-i} + \sum_{i=0}^{k_6} \eta_{6i}(TGC)_{t-i} \\
& + \sum_{i=0}^{k_7} \eta_{7i}(IR)_{t-i} + \varepsilon_t \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \ldots \qquad (8)
\end{aligned}
$$

The ARDL model for the long run coefficients of Model-2 Equation (7) is to capture the long run energy consumption effects on agricultural output in Pakistan.

$$
\begin{aligned}
AGRI = {} & \theta + \sum \theta (TELF) + \sum \theta (RGFCF) + \sum \theta (TOC) \\
& + \sum \theta (TEC) + \sum \theta (TGC) + \sum \theta (ACRDT) + \mu \quad \ldots \qquad (9)
\end{aligned}
$$

Now we will find the short coefficient of the model with error correction term. We will use the short run error correction estimates of ARDL model. The difference between actual and estimated values is considered as error correction term. Error correction term is defined as adjustment term showing the time required in the short run to move toward equilibrium value in the long run. The coefficient of error term has to be negative and significant. The short run error correction (ECM) model of Model-1 Equation (6) to find out impact of energy consumption on economic growth in time adjusting frame work to attain long run equilibrium is as follows;

$$
\begin{aligned}
\Delta RGDP_t = {} & \rho_0 + \sum_{i=1}^{k_1} \rho_{1i}\, \Delta(\mathrm{RGDP})_{t-i} + \sum_{i=0}^{k_2} \rho_{2i}\, \Delta(\mathrm{RGFCF})_{t-i} + \sum_{i=0}^{k_3} \rho_{3i}\Delta(\mathrm{TELF})_{t-i} + \sum_{i=0}^{k_4} \rho_{4i}\, \Delta(\mathrm{TOC})_{t-i} \\
& + \sum_{i=0}^{k_5} \rho_{5i}\, \Delta(TGC)_{t-i} + \sum_{i=0}^{k_6} \rho_{6i}\, \Delta(TEC)_{t-i} + \sum_{i=0}^{k_7} \rho_{7i}\, \Delta(IR)_{t-i} + \lambda(ECM)_{t-1} + \varepsilon_t \quad \ldots \qquad (10)
\end{aligned}
$$

ECM_{t-1} is lagged error correction term of the model and λ is the coefficient value of ECM which is the speed of adjustment.

The short run (ECM) model of Model-2 Equation (7) to find out impact of energy consumption on Agricultural output in Pakistan in time adjusting frame work to attain long run equilibrium is as follows.

$$
\begin{aligned}
\Delta\, AGRI_t = {} & \sigma_0 + \sum_{i=1}^{k_1} \sigma_{1i}\, \Delta(\, RGFCF)_{t-i} + \sum_{i=0}^{k_2} \sigma_{2i}\, \Delta(\, TELF)_{t-i} + \sum_{i=0}^{k_3} \sigma_{3i}\Delta(\, TOC)_{t-i} \\
& + \sum_{i=0}^{k_4} \sigma_{4i}\Delta(\, TGC)_{t-i} + \sum_{i=0}^{k_4} \sigma_{4i}\Delta(\, TEC)_{t-i} + \omega(ECM)_{t-1} + \mu_t \quad \ldots \qquad (11)
\end{aligned}
$$

ECM_{t-1} is lagged error correction term of the model and ω is the coefficient value of ECM which is the speed of adjustment.

The Error Correction Term (EC_{t-1})

The error correction term (EC_{t-1}), which instrument the adjustment speed in the dynamic model for restoring equilibrium. Banerjee, *et al.* (1998) grasped that a highly significant error correction term is further proof of the existence of stable long run relationship. The negative sign of error correction term also give uni-directional effect of variables.

4. RESULTS AND DISCUSSIONS

After discussing the data sources, we analyse the impact of disaggregate energy consumption on economic growth and Agricultural output on empirical grounds. To analyse these issues, we will provide an insight to draw some conclusions on the basis of empirical results of this research. The results are discussed as follows.

(a) Descriptive Analysis

The descriptive statistics of the study are presented in the Table 1. Descriptive statistics consists of procedures used to summarise and describe the characteristics of a set of data. The table shows the averages values, standard deviation, skewness, kurtosis and J. Bera values of the selected variables.

Table 1

Descriptive Statistics of Variables

Variables	Mean	Std. Dev.	Skewness	Kurtosis	J.Bera	Prob.
AGRI	587531.9	737717.6	1.70	5.41	28.33	0.00
IR	9.633333	5.732839	1.87	7.08	50.07	0.00
RGDP	1507061	1991864	1.07	2.38	8.16	0.01
RGFCF	8910.988	5118.798	0.76	2.87	3.81	0.14
TEC	32961.79	22153.06	0.40	1.96	2.77	0.24
TELF	31.31373	8.480152	0.26	1.98	2.13	0.34
TGC	550732.2	371132	0.78	2.41	4.53	0.10
TOC	10465494	5656927	-0.00	1.44	3.93	0.13
ACRDT	43420	66478	2.00	5.85	39.39	0.00

Source: Authors' calculations.

Our study is based on the 41 years of annual observation for the period 1972-2011. Descriptive statistics on some important variables are reported in Table 1. We have found that the average agriculture productivity is 587531.9 million rupees with 737717.6 units' standard deviation. The mean value of the total oil consumption, total gas consumption is 10465494 units, 32961.79 units and 550732.2 units respectively with low variability as compared with mean values. The value of Jarque- Bera JB test states that residual of the core variables like RGFCF, TEC, TELF, TGC and TOC are normally distributed. The values of the co-efficient of skewness show that almost all the variables are positively skewed expect total oil consumption.

(b) ADF Test for Stationarity

Table 2 explains the summary statistics of ADF test. The results of the test indicate that some variables are stationary at level and others are stationary at first difference. The findings of the study provide the justification of ARDL Approach.

Table 2

Results of ADF Test

Variables	ADF Statistic (At Level)		ADF (With First Difference)		Order of Integration
	Intercept	Trend and Intercept	Intercept	Trend and Intercept	
IR	–3.252	–3.394	–	–	I(0)
ACRDT	3.503	2.740	–1.848	–2.754	I(1)
RGDP	0.648	–1.289	–5.966	–6.346	I(1)
TELF	1.728	–0.477	–7.827	–8.092	I(1)
RGFCF	–0.602	–3.344	–	–	I(0)
TOC	–0.993	–3.568	–	–	I(0)
TGC	1.414	–2.831	-3.783	-2.948	I(1)
TEC	–2.076	–3.229	–	–	I(0)
AGRI	3.503	2.740	–1.848	–3.754	I(1)

Note: Results are based on authors' calculations.

Bounds Test for Co-integration

In the first step the existence of the long run relationship among the variables is needed. We have used Bound Testing Approach in order to examine the long run relationship. Table 3 interprets the findings of Wald-Test (F-Statistics) for long-run relationship.

Table 3

Results of Bound Test for Co-integration

Equations	F-statistic Calculated	Upper Bound Critical Value	Conclusion
Model-1 Equation (6) RGDP / RGFCF, TELF, TOC, TGC, TEC, IR	7.42 [0.0002]	4.90 (99%)	Co-integration exists
Model-2 Equation (7) ARGI / RGFCF, TELF, TOC, TGC, TEC, ACRDT	13.51 [0.000]	4.90 (99%)	Co-integration exists

Note: Computed F-statistic: 7.42 and 13.51 (Significant at 1 percent marginal values). Critical Values at $k = 7-1=6$ and $k = 7-1=6$ are cited from Pesaran, *et al.* (1999), Table CI (V), Case V: Unrestricted intercept and Unrestricted trend. The numbers in parenthesis shows the probabilities of F-statistic.

The value of F-statistics based on Wald test is given in second column. The upper bound values are reported in third column of Table 2. The results of the test indicate that there exits long-run relationship among the variables in both models.

Estimates of Energy Consumption and Economic Growth

The long-run estimates of the model-1 are reported in Table 4. The dependant variable is economic growth which is proxied as real GDP whereas RGFCF, TELF, TOC, TEC and TGC, IR are independent variables.

Table 4

Long- run Results of Disaggregate Energy Consumption and Economic Growth

Estimated Long Run Coefficients using the ARDL Approach			
ARDL(1,0,2,0,1,2,1) selected based on Schwarz Bayesian Criterion			
Dependent Variable is RGDP			
Regressor	Coefficient	Standard Error	T-Ratio [Prob]
RGFCF	604.54	332.51	1.81 [.083]
TELF	588561	523156	1.12 [.273]
TOC	.90	.29	3.00 [.007]
TGC	15.63	6.30	2.47 [.021]
TEC	–346.85	157.78	–2.19[.039]
IR	–69002	60625.9	–1.13 [.267]
C	–1.17	9592168	–1.22 [.235]
T	–779741	351826.6	–2.21 [.037]

Note: Results are based on Authors' calculations using Microfit 4.1.

We have observed that the value of regression coefficient of Real Gross Fixed Capital Formation (RGFCF) that is 604.54 which means that the one unit increase in Real Gross Fixed Capital Formation increases the economic growth (RGDP) by 604.54 units and this effect is strong and statistically significant. The expansion of infrastructure directly stimulates productive activities. The other channel may be that investment spending in various projects raises overall productivity and economic growth. Our results stay in line with Khan and Reinhart (1990); Blomstrom, *et al.* (1994) who find positive relationship between investment and growth.

Table 5

Short Run Estimates of Disaggregate Energy Consumption on Economic Growth

ARDL (1,0,2,0,1,2,1) selected based on Schwarz Bayesian Criterion			
Dependent variable is dRGDP			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
dRGFCF	229.9852	87.6733	2.6232[.014]
dTELF	153071.4	101752.5	1.5044[.145]
dTELF1	–205340.1	101328.0	–2.0265[.053]
dTOC	.34272	.077428	4.4263[.000]
dTGC	10.8104	2.3522	4.5958[.000]
dTEC	–92.0338	52.6229	–1.7489[.092]
dTEC1	–152.8186	54.7032	–2.7936[.010]
dIR	2370.6	16643.9	–14243[.888]
dC	–4460483	3357701	–1.3284[.196]
dT	–296635.0	113131.6	–2.6220[.014]
ecm(–1)	–.38043	.11781	–3.2290[.003]
ecm = RGDP –604.54*RGFCF –588561.3*TELF –.90*TOC –15.63*TGC + 346.8594*TEC + 69002.1*IR + 1.17E*C + 779741.9*T			
R-Squared .76189		R-Bar-Squared .61036	
DW-statistic 2.3488		F-stat. F(10, 26) 7.0393[.000]	

Note: Results are based on Authors' calculations using Microfit 4.1.

The coefficient of the employed labour force is although positive but insignificant. Our findings are matched with conventional neo-classical theories of growth [see Barrow and Sala-i-Martin (1995)].

The core variables of the study are energy variables i.e., total energy consumption, total gas consumption and total electricity consumption. We have noted in the present study that total oil consumption directly influence the economic growth. The value of the coefficient of oil consumption is 0.90 which means that an increase of one unit in total oil consumption raises real GDP about 0.90 units. The same results are found in the short run. The findings support the theoretical results. The reason may be that the wheel of the economic life cannot be run without oil now-a-days because of mechanisation and technological progress.

We have observed that the coefficient of total gas consumption is positive and highly significant. The real GDP increases almost 15.6 units due to one unit increase in total gas consumption. It is noted that the third variable of the energy turns out to be negative. The coefficient of the total electricity consumption is (–346.85) and statistically significant. The short run findings also indicate negative impact on growth. The analysis concludes that electricity is considered as limiting factor to economic growth in Pakistan. The reason may be that the continuous short fall of the electricity and electricity supply shock are the main causes of growth deterioration. Our results support the [Javaid, *et al.* (2013); Kakar and Khilji (2011); Shahbaz, *et al.* (2013); Onakoya, *et al.* (2013) and Yuan, *et al.* (2007)] findings.

The inflation rate is used as control variable in the growth model. The analysis concludes that the effect of inflation rate on economic growth is negative and statistically insignificant. Theoretically, it is sound because rising prices cause an increase in the cost of production. As a result production decreases and ultimately economic growth declines.

Interpretation of Error Correction Term (EC_{t-1})

The coefficient of ecmt-1 for Model-1 is equal to (–0.38) for the short-run model and implies that deviation from the long-term economic growth is corrected by 38 percent over each year at 1 percent level of significance.

Estimates of Disaggregate Energy Consumption and Agricultural Output

The value of regression coefficient of real Gross Fixed Capital Formation (RGFCF) is 8.92 which means that the one unit increase in real Gross Fixed Capital formation raises the Agricultural output by 8.92 units. The reason may be that investments in agriculture input industry like tractors, thrashers, tube wells and pesticides increase along with an increase in the income of the farmer. Therefore, per capita saving rate increases and ultimately growth per capita increases [Barro (1991)].

Table 6

Long- Run Estimates of Disaggregate Energy Consumption and Agricultural Output

ARDL(1,2,0,2,1,2,2) selected based on Schwarz Bayesian Criterion			
Dependent Variable is AGRI			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
RGFCF	8.92	23.65	.377[.710]
TELF	3033	12712	.238[.814]
TOC	.054	.017	3.114[.006]
TGC	1.81	.47	3.817[.001]
TEC	–9.41	8.23	–1.142[.267]
ACRDT	8.83	.95	9.260[.000]
C	–208966	231783	–.901[.379]
T	–33472	11111	–3.012[.007]

Note: Results are based on Authors' calculations using Microfit 4.1.

We have observed that the value of regression coefficient of Employed Labour Force (TELF) is 3033. This means that the one unit increase in Employed Labour Force increases agricultural output by 3033 units and the result is statistically insignificant.

We have found that the coefficient of total gas consumption is 1.81 and statistically highly significant. The agricultural product increases by about 1.8 units due to one unit increase in total gas consumption. The results may be justified on the sound reasoning that fertiliser and pesticides producing industries have shifted their production process from electricity usage to gas usage considering it cheaper source of energy.

Table 7

Short Run Effects of Disaggregate Energy Consumption on Agricultural Output

Error Correction Representation for the Selected ARDL Model			
ARDL(1,2,0,2,1,2,2) selected based on Schwarz Bayesian Criterion			
Dependent Variable is dAGRI			
Regressor	Coefficient	Standard Error	T-Ratio[Prob]
dRGFCF	–1.03	7.19	–.14[.887]
dRGFCF1	–17.82	7.89	–2.25[.033]
dTELF	1409.2	5927	.23[.814]
dTOC	.007	.006	1.15[.259]
dTOC1	–.016	.007	–2.07[.049]
dTGC	.104	.18	.55[.582]
dTEC	-6.78	5.71	–1.18[.247]
dTEC1	–23.28	5.10	–4.55[.000]
dACRDT	.769	1.19	.64[.527]
dACRDT1	–1.92	1.17	–1.63[.114]
dC	–97067	109958	–.88[.386]
dT	–15548	5548.90	–2.80[.010]
ecm(-1)	–.464	.102	–4.52[.000]
ecm = AGRI –8.9289*RGFCF –3033.7*TELF –.054952*TOC –1.8115*TGC + 9.4111*TEC –8.8307*ACRDT + 208966.6*C + 33472.2*T			
R-Squared .98		R-Bar-Squared .97	
DW-statistic 1.83		F-stat. F(12, 24) 121.65[.000]	

Note: Results are based on Authors' calculations using Microfit 4.

The estimated coefficient of Total Oil Consumption is .054. This means that the one unit increase in Total Oil Consumption increases agricultural output by .054 units. The estimated coefficient of Total Electricity Consumption (TEC) is –9.41 which implies that agricultural output is affected negatively by electricity consumption and is statistically significant. The agricultural credit is contributing positively in boosting up economic growth as coefficient of agricultural credit is 8.83 and is significant. Results are consistent with [Ayaz, *et al.* (2011)]. Formal credit directly influences agricultural productivity through investment and financing of fertilisers and seeds [Qureshi and Shah (1992); Jehanzeb, *et al.* (2008)].

Interpretation of Error Correction Term (EC_{t-1})

The value of Ecmt-1 for Model-2 is (–.46) which implies that the short run variables approach to long run variables by 46 percent each year. Negative and significant value of error correction term also provides further proof of existence of long run and unidirectional relationship [Bannerjee, *et al.* (1998)].

Diagnostic Tests

J-B normality test for residual is conducted to see residuals are normally distributed or not because one of the assumptions of CLRM is residuals are normally distributed with zero mean and constant variance. Breusch-Godfrey LM test is conducted to check the serial autocorrelation in our model. Autoregressive conditional heteroskedasticity (ARCH) is conducted to check the autocorrelation in the variance of error term. The outcomes of all these tests are reported in the Tables 8 and 10.

Table 8

Diagnostic Test

Diagnostic Tests of Model-1 [RGDP | RGFCF, TELF, TEC, TGC, TOC, IR]		
Test Statistics *	LM Version *	F Version *
* A:Serial Correlation*	CHSQ (1) = 1.6304[.202]	F(1, 21)= .96801[.336]*
* *	* *	
* B:Functional Form *	CHSQ (1) = 3.6478[.066]	F(1, 21)= 2.2968[.145]*
* *	* *	
* C:Normality	CHSQ (2) = 2.1778[.337]	* Not applicable *
* *	* *	
* D:Heteroscedasticity*	CHSQ (1) = .36585[.545]	F(1, 35)= .34953[.558]

Source: Authors' calculation using Microfit 4.1.

Table 9

Diagnostic Test

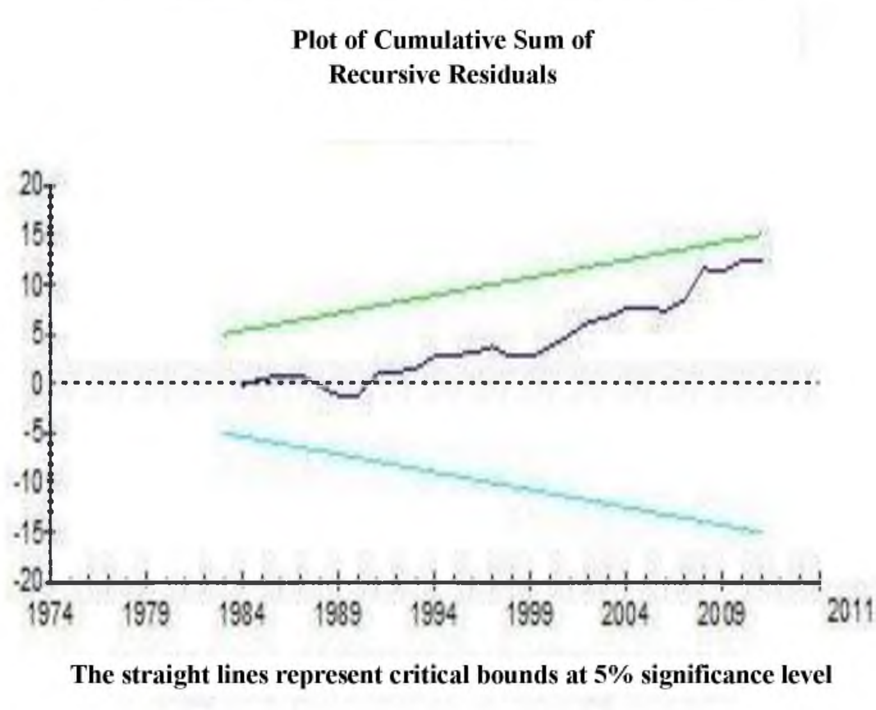
Diagnostic Tests of Model-2 [AGRI | RGFCF, TELF, TEC, TGC, TOC, ACRDT]		
Test Statistics *	LM Version *	F Version *
* A:Serial Correlation*CHSQ (1)	= .53399[.465]*	F(1, 18)= .26358[.614]*
* B:Functional Form *CHSQ (1)	= 2.5889[.118]*	F(1, 18)= 1.3542[.260]*
* C:Normality *CHSQ (2)	= 2.4167[.299]	* Not applicable *
* D:Heteroscedasticity*CHSQ (1)	= .46974[.493]*	F(1, 35)= .45007[.507]*

Source: Authors' calculation using Microfit 4.1.

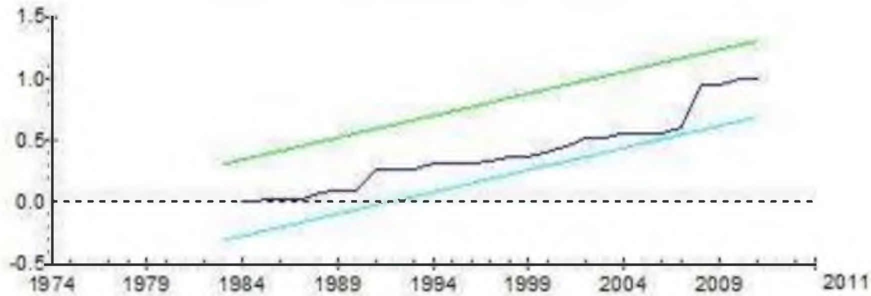
Stability Test

In order to check the stability of the Models, we plot the cumulative sum of recursive residuals CUSCUM and cumulative sum of recursive residuals of square CUSUMS. The results show that coefficients in our estimated models are stable as the graph of CUSUM and CUSUMS statistics lies in the critical bounds. The absence of divergence in CUSUM and CUSUMS graphs confirm that in our ARDL Models, short run and long run estimates are stable.

Stability Test for Model-1 [RGDP | RGFCF, TELF, TEC, TGC, TOC, IR]



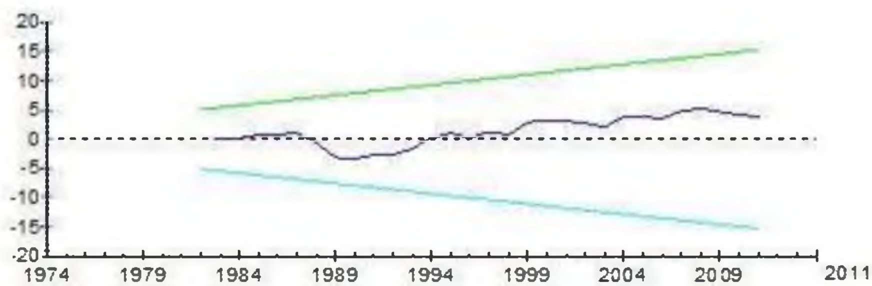
Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

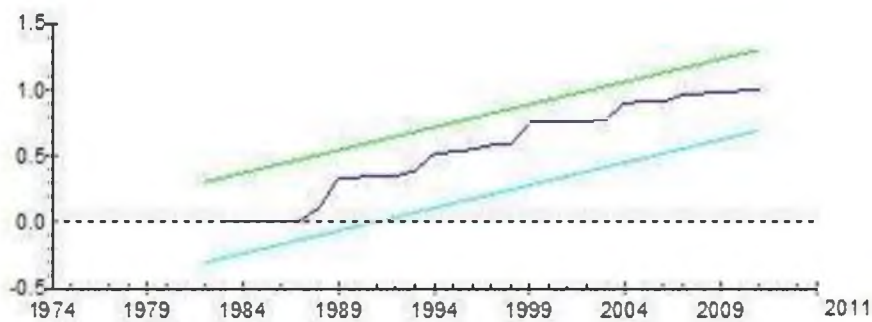
Stability Test for Model-2 [AGRI | RGFCF, TELF, TOC, TEC, TGC, ACRDT]

Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

Plot of Cumulative Sum of
Recursive Residuals



The straight lines represent critical bounds at 5% significance level

5. CONCLUSIONS

In this study, we have analysed the impact of disaggregate energy consumption on economic growth and Agricultural output on empirical grounds with respect to Pakistan. Study has used ADF test which indicates mixed results with different order of integration. Existence of long run relationship among variables is examined for both models. Long run estimation and error correction representation of both models have been discussed and their interpretations are made. Findings of the study conclude that disaggregate energy consumption, economic growth and agricultural output are interlinked with each other in short as well as in long run.

The empirical analysis of disaggregate consumption on economic growth and on agricultural output leads to a number of conclusions for policy formulation. Electricity consumption and economic growth puts some essential policy implications on the economy of Pakistan. The unidirectional relationship of electricity consumption to economic growth and agricultural output leads us to draw a conclusion that shortage of electricity supply at the prevailing level can harm Pakistan's economic growth and agricultural output. As, consumption of electricity can influence national and agricultural output as it is the main source of energy, that is why it is significant to maintain the supply of electricity according to its demand. And since in cyclical sense economic fluctuations are also caused due to changes in electricity consumption which implies that electricity may be a leading indicator for business cycle. Another important implication is that as oil consumption and gas consumption are contributing positively to economic growth and agricultural growth. therefore, Pakistan energy sources (i.e., oil, coal and gas) other than electricity should be enhanced for sustainable economic growth because Pakistan production sectors like agricultural sector also rely on electricity consumption mainly and increasing demand of electricity as compared to its supply and insufficient installed capacity reduce agricultural as well as national output.

REFERENCES

Ahmed, W., K. Zaman, S. Taj, R. Rustam, M. Waseem, and M. Shabir (2013) Economic Growth and Energy Consumption Nexus in Pakistan. *South Asian Journal of Global Business Research* 2:2, 251–275.

Alam, S. and M. S. Butt (2001) Assessing Energy Consumption and Energy Intensity Changes in Pakistan: An Application of Complete Decomposition Model. *The Pakistan Development Review* 40:2, 135–147.

Apergis, N. and E. Payne (2010) Natural Gas Consumption and Economic Growth: A Panel Investigation of 67 Countries. *Applied Energy* 87, 2759–2763.

Aqeel, A. and M. S. Butt (2001) The Relationship between Energy Consumption and Economic Growth in Pakistan. *Asia- Pac. Dev. J.* 8, 101–110.

Ayaz, S., S. Anwar, M. H. Sial and Z. Hussain (2011) Role of Agricultural Credit on Production Efficiency of Farming Sector in Pakistan – A Data Envelopment Analysis. *Pak. J. Life Soc. Sci.* 9:1, 38–44.

Banerjee, A., J. J. Dolado, and R. Mestre (1998) Error-Correction Mechanism Tests for Cointegration in a Single-Equation Framework. *Journal of Time Series Analysis* 19, 267–283.

Barro, R. (1991) Economic Growth in a Cross-section of Countries. *Quarterly Journal of Economics* 106, 407–443.

Barro, R. J. and X. Sala-i-Martin (1995) *Economic Growth*. New York: McGraw-Hill.

Blomstrom, M., R. Lipsey, and M. Zejan (1994) What Explains Growth in Developing Countries? In W. Baumol, R. Nelson and E. Wolff (eds.) *Convergence of Productivity: Cross-National Studies and Historical Evidence*. Oxford and New York: Oxford University Press. 243–59.

Dantama, Y. U., Y. Z. Abdullahi, and N. Inuwa (2011) Energy Consumption—Economic Growth Nexus in Nigeria: An Empirical Assessment Based on ARDL Bound Test Approach. *European Scientific Journal* 8:12.

Hondroyiannis, G., S. Lolos, and E. Papapetrou (2002) Energy Consumption and Economic Growth: Assessing the Evidence from Greece. *Energy Economics* 24, 319–336.

Javid, A. Y., M. Javid, and Z. A. Awan (2013) Electricity Consumption and Economic Growth: Evidence from Pakistan. *Economics and Business Letters* 2, 21–32.

Kakar, Z. K. and B. A. Khilji (2011) Energy Consumption and Economic Growth in Pakistan. *Journal of International Academic Research* 11:1.

Khan, M. S. and C. M. Reinhart (1990) Private Investment and Economic Growth in the Developing Countries. *World Development* (January).

Mozumder, P. and A. Marathe (2007) Causality Relationship between Electricity Consumption and GDP in Bangladesh. *Energy Policy* 35, 395–402.

Nwosa, P. I. and T. O. Akinbobola (2012) Aggregate Energy Consumption and Sectoral Output in Nigeria. *African Research Review* 6:4, 206–215.

Oh, Wankeun and Kihoon Lee (2004) Energy Consumption and Economic Growth in Korea: Testing the Causality Relation. *Journal of Policy Modeling* 26: 973–981.

Ojinnaka, I. P. (1998) Energy Crisis in Nigeria: The Role of Natural Gas. *CBN Bulletin* 22:4, 8–12.

Onakoya, A. O., O. A. Jimi – Salami, and B. O. Odedairo (2013) Energy Consumption and Nigerian Economic Growth: An Empirical Analysis. *European Scientific Journal* 9:4, 25–40.

Paul, S. and R. N. Bhattacharya (2004) Causality between Energy Consumption and Economic Growth in India: A Note on Conflicting Results. *Energy Economics* 26, 977– 983.

Pesaran, M. H. and Y. Shin (1999) An Autoregressive Distributed Lag Modelling Approach to Cointegration Analysis. In S. Strom, A. Holly and P. Diamond (eds.) *Econometrics and Economic Theory in the 20th Century: The Ragner Frisch Centennial Symposium*. Cambridge: Cambridge University Press.

Pesaran, M. H., Y. Shin, and R. J. Smith (2001) Bounds Testing Approaches to the Analysis of Level Relationships. *Journal of Applied Econometrics* 16:3, 289–326.

Pew Centre on Global Climate Change and the National Commission on Energy Policy.

Qureshi, S. K. and A. H. Shah (1992) A Critical Review of Rural Credit Policy in Pakistan. *The Pakistan Development Review* 31:4 871801.

Shah, M., K. Khan, H. Jehanzeb and Z. Khan (2008) Impact Of Agricultural Credit On Farm Productivity And Income Of Farmers In Mountainous Agriculture In Northern Pakistan: A Case Study of Selected Villages in District Chitral. *Sarhad. J. Agri* 24:4.

Shahbaz, M. and M. Feridun (2011) Electricity Consumption and Economic Growth Empirical Evidence from Pakistan. *Qual Quant*.

Shahbaz, M., H. H. Lean, and A. Farooq (2013) Natural Gas Consumption and Economic Growth in Pakistan. *Renewable and Sustainable Energy Reviews* 18, 87–94.

Solow, R. M. (1956) A Contribution to the Theory of Economic Growth. *The Quarterly Journal of Economics*, 65–94.

Sorrell, S. (2009) Jevons' Paradox revisited: The Evidence for Backfire from Improved Energy Efficiency. *Energy Policy* 37, 2310–2317.

Van Zon and Yetkiner (2003) An Endogenous Growth Model with Embodied Energy-saving Technical Change. *Resource and Energy Economics* 25, 81–103.

Wei, T. (2007) Impact of Energy Efficiency Gains on Output and Energy Use with Cobb-Douglas Production Function. *Energy Policy* 35, 2023–2030.

Worrell, E., L. Price, and LBNL (2001) Pew Centre/NCEP 10-50. Improving Industrial Energy Efficiency in the U.S.: Technologies and Policies for 2010 to 2050. Workshop proceedings. "The 10-50 Solution: Technologies and Policies for a Low-Carbon Future."

Yang, H. Y. (2000) A Note on the Causal Relationship Between Energy and GDP in Taiwan. *Energy Economics* 22:3, 309–317.

Yuan, J., C. Zhao, S. Yu, and Z. Hu (2007) Electricity Consumption and Economic Growth in China: Cointegration and Co-feature Analysis. *Energy Economics* 29:6, 1179–1191.

Comments

The paper titled "Disaggregate Energy Consumption, Agriculture Output and Economic Growth: An ARDL Modelling Approach to Co-integration" touches upon an important subject of policy making in the context of economic growth.

Having said that let me point out some of the weakness which to my understanding if improved can make this paper very useful both for academia and policy-makers.

(i) The use of the econometrics technique such as ARDL is a norm now a day, hence putting the same in the title does not signifies it any more. So I would recommend that the authors should stick to the economic title only.

(ii) Putting such words on the title page, e.g. in the abstract *data ranges from 1972-2011 from a reliable source…* leaves the reader thinking that is it an insider job. Such mentioning is taken care of in the data and methodology section. Subsequently these sources are also not mentioned in data section.

(iii) There is a need to carefully review and state the objectives of the study.

(iv) There is no discussion of why the authors have just picker the agricultural out put to be a representative of the sub components of GDP and leave out other potential sectors which are also contributing to the economic growth such as manufacturing, communications etc.

(v) The descriptive analysis is out of context and does not help the reader in establishing the linkage between the variables of interest. The use of data is also not appropriate such as Figure 2 is totally out of context and not discussed at all.

(vi) There is a confusion across the paper as to authors are focusing on the consumption, the efficient consumption of the energy sources at disaggregated level or the energy-mix in use.

(vii) The qualification such as…. The study also fulfils a number of imperfections of previous studies such as not using appropriate technique for co-integration, model specification and methodological issues requires the literature review to be set accordingly and the next coming sections such as the methodology etc. to further qualify that.

(viii) Variables abbreviations such as *RGFCF, TELF…* does not convey its description.

(ix) There is no model as such, mentioning the variables in a simple production function with variables of interest a arguments of a function is not a model.

(x) Tables when placed needs an explanation, e.g., Table 1: on the descriptive statistics.

(xi) For estimation of the regression ARDL approach is used:

 (a) The results for unit root test are not provided for inclusion of intercept and trend or there is no plot of the data. Further for robust results often PP test is also applied but not in this case.

 (b) Now once it was observed that all the variables at I(1) except IR and RGFCF (which I don't know what these are) which are I(0). Then a simple cointegration method like Johanson and Jusilus or Engle and Granger was more appropriate leaving these two, as the ARDL is adopted if the variables under consideration have different order of integrations (i.e. a mix of I(0) and I(1)).

(c) While comparing the wald-F test for existence of cointegration Pesaran, *et al.* (2001) tables are used, which were for large samples (500-1000), for our case where the total observations are around 40 we have to use the tables provided by Naryan (2005) otherwise it may get non-parsimonious results as the F-test used here has a non-standard distribution and depends on the (1) Variables being I(0) or I(1), (2) No of repressors, (3) Intercept and/or trends and the (4) sample size. So we can not use the old tables for exploring the critical bound.

(d) The Cusum and Cusum Square tests are showing a unique picture, where the bounded line appears only the latter years and not for the whole sample period, please explain.

(xii) In the results description what bothers me is the results and there explanation, e.g. 1 unit Oil consumption leading to an increase of about just 0.90 units in the GDP. First I am unaware as to the use of Oil consumption units used here are in energy units or expenditures on oil consumption. Second these results are somewhat unexpected also not validated with the help of other studies.

(xiii) There is a strong possibility of multicollinearity in the estimation as both the Oil consumption and electricity usage is taken as explanatory variables.

(xiv) Further the results are totally in abeyance of any possible explanation. e.g. electricity consumption presents a negative relationship with economic growth.

(xv) Further taking inflation to be linked with economic growth means we may need to explore the sacrifice ratio, but that has to be through the demand side, whereas in Pakistan inflation may be arising from the supply side.

(xvi) Investment in human capital is not synonymous to R&D.

(xvii) The paper needs a through reading and then editing.

(xviii) Conclusions are based on empirical work which is largely not reflecting the true logics. Further basing policy recommendations which are not arrived at from the authors estimation should not be put forth.

Over all the study needs a thorough revision both in the context of theoretical understanding and the econometric methodology on how to estimate it.

Mahmood Khalid

Pakistan Institute of Development Economics,
Islamabad.