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A Time Series Analysis of Energy Consumption, Energy Prices and Economic Growth in Pakistan

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Abstract

The present study is conducted to investigate the impact of Energy Consumption (EC) on the Economic Growth (EG) in Pakistan by using a trivariate model. Time series data of macroeconomic determinants of Energy Consumption (EC), Energy Prices (EP) and Economic Growth (EG) are used to analyze the linkage among the variables. Annual data are collected from different published sources like World Development Indicators (WDI), BP Statistical Review and Economic Surveys of Pakistan for the period 1971-2014. Augmented Dickey Fuller (ADF) unit root test and Phillips Perron unit root test are used to examine the stationarity of data and all the variables are found stationary in differenced form. Short run and long run linkage among the variables is examined through Johansen co-integration test and the results confirm the existence of one co-integrating vector among the variables. Granger causality test under Vector Error Correction Model (VECM) is applied to observe the direction of between Energy Consumption (EC), Energy Prices (EP) and economic growth (EG). Unidirectional causality is found from Economic Growth (EG) to Energy Consumption (EC) and unidirectional causality from Energy Consumption (EC) to Energy Prices (EP) is also found in short run as well as in long run. On the basis of result of the study, conservation policy regarding to the Energy Consumption (EC) is suggested with a negligible or no effect on Economic Growth (EG).

Keywords: Energy Consumption; Economic growth; Energy prices; Vector Error Correction Model (VECM)

Introduction

Consumption of energy or power is referred as energy consumption. Energy consumption is interlinked with economic growth and this issue has become the main concern for a number of researches in the last few decades. Energy enhances the productivity and performance of factors of production, thereby an economy get developed. Therefore, utilization of energy is acknowledged the key determinant of growth of an economy that is why the association between growth of an economy and usage of energy has considered the main interest for the researcher, policy makers and economists (Chandran *et al.*, 2010).

Globalization has changed the entire world and also created a number of issues for different economies. Among these issues, energy has received considerable attention. Energy requirement is growing day by day in the universe, which constitutes serious energy issues. According to the energy outlook report of International Energy Agency (IEA), the requirement for energy in overall world is estimated to increase by 50 percent in the next 15 years until 2030 due winged rise in the demand for energy by the time (IEA, 2014).

The demand for energy in Pakistan is also increasing rapidly for the last few decades, which results in a serious energy crisis and influence the industrial sector badly. In the last 18 years, about 86 percent increase in primary energy consumption is recorded in Pakistan, from 37,300 thousand tons of oil equivalent (ktoe) in 1995-96 to 69,600 thousand tons of oil equivalent (ktoe) in 2013-14. For the same period, 39 percent increase in oil consumption, 45 percent increase in electricity consumption, more than 100 percent rise in natural gas consumption, 100 percent increase in coal consumption and 72 percent increase in total energy consumption is recorded (BP Stats, 2014). Figure 1 shows the comparison of energy usage between Pakistan and World.

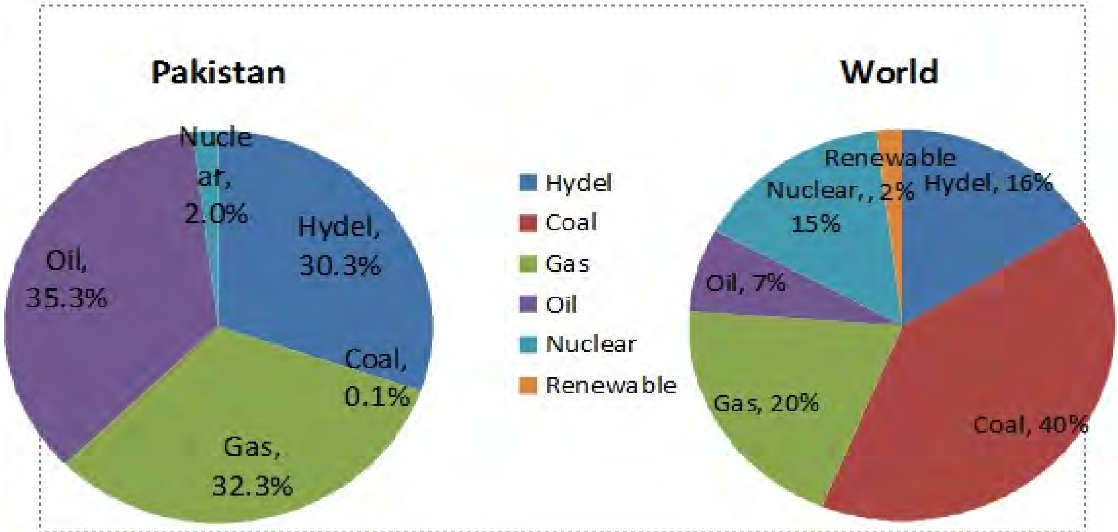

Figure 1. Pakistan's energy mix in comparison to the global energy mix (Source: Solar Power Production in Pakistan)

Economic growth is concerned with the economic activity and increase in production. Gross Domestic Production (GDP) per capita is better indicator of growth than GDP itself. A sustained rate of growth for a long time period brings remarkable change in Gross Domestic Product (GDP) of a country.

Pakistan lies among the least developed and poorest countries of Asia. Economic growth of Pakistan mainly depends on semi-industrialized manufacturing sector, agriculture sector and remittances (Trading Economics, 2015). Economy of Pakistan, on the basis of Purchasing Power Parity (PPP), is on 26^{th} largest economy of the world and 42^{nd} largest economy on the basis of nominal Gross Domestic Product (GDP) (Leghari, 2007). In 2014, the rate of growth for total production (GDP) in Pakistan is 4.14 percent while the average rate of growth in aggregate production (GDP) for the period 1954-2014 is 4.92 percent. Economy of Pakistan has experienced 10.22 percent as the highest rate of growth in domestic output (GDP) in 1954 while -1.80 percent as the lowest rate of growth in aggregate output (GDP) in 1952 (Trading Economics, 2015). According to World Bank, Pakistan is placed among the bottom eight economies of South Asia and projected as second lowest growing economy in South Asia after Bangladesh with 4.4 percent rate of growth in aggregate output (GDP) in 2016 (The Express Tribune, 2015).

Traditionally, the national output has associated with labor, physical capital and technological advancement to enhance productivity (Lucas, 1988). In 20^{th} century energy has considered the main factor for growth of an economy. Growth of an economy is intently associated with the utilization of energy because higher rate of growth for production increases the usage of energy and more efficient use of energy leads the economy towards growth (Halıcıoglu, 2009).

The nexus between the utilization of energy and growth of an economy is significant in view of policy implications and hence policy makers and economists are interested about the association between these variables, some economists suggest the economic growth as key determinant of energy consumption (Li, 2003; Crompton and Wu, 2005;Skeer and Wang, 2007). Many researchers have investigated the nexus among the usage of energy and growth of an economy. The studies also attempted to identify the direction of causality among the utilization of energy and growth of an economy but still there is no consent on the issue.

For example, economic growth Granger causes energy use in long run likewise in short run in case of India (Cheng, 1999). On contrary, energy consumption Granger causes Gross Domestic Production (GDP) in case of Croatia (Gelo, 2009). Bidirectional causality was found in case of panel of Pacific Island countries (Mishra *et al.*, 2009). On contrary, no causality was found between the utilization of energy and aggregated national output (GNP) of USA (Yu and Hwang, 1984). The contradictory results for causality between the utilization of energy and growth of an economy are may be due to different geographical conditions of countries, difference in the available resources and technologies, difference in the econometric techniques and the difference in the period selected to conduct the analysis (Ouedraogo, 2013).

The relationship between the utilization of energy and Gross Domestic Product (GDP) can be investigated on the basis of four hypotheses (Payne, 2009, 2010). First is the growth hypothesis, which states that energy use Granger causes growth of the economy. It indicates that energy consumption, directly or indirectly, plays crucial role for the growth of an economy. Second is the conservation hypothesis, which states that growth of an economy Granger causes the utilization of energy. Conservation hypothesis indicates a less energy dependent economy, which wants to reduce CO_2 (Carbon Dioxide) emissions, to manage waste and enhance the efficiency without reducing the Gross Domestic Production (GDP). In unidirectional causality, economic growth may cause a reduction in energy use in a result of political constraints or mismanaged resources that results in the reduction of demand for goods and services as well as for energy (Payne, 2010).Third is the feedback hypothesis and it states that the utilization of energy and growth of the economy are complementary to each other. According to this hypothesis, bidirectional causality exists between utilization of energy and growth of the economy.

On the basis of above hypotheses, this study will be conducted for the economy of Pakistan. Pakistan is the sixth most populated country with total population 185.1 million growing at 1.64 percent per year (Worldometers, 2015). According to International Monetary Fund and World Bank ranking, Pakistan falls in category of lower middle income countries with $ 1368 per capita income. Pakistan is naturally blessed with a great number of resources for energy generation like natural gas, solar energy, hydel power generation, wind and coal. Among these resources of energy, mostly are unexploited or underutilized. Current energy crisis in Pakistan is a result of this mismanagement. The poor energy supply conditions are the result of lack of investment in energy sector. Main hurdle for the growth of Pakistan is poor infrastructure in energy sector and impotent provisions of energy services.

It has proven by literature that energy is main determinant of growth in both developed and under developed countries. Pakistan is bestowed with conventional energy sources as well as non-conventional energy sources and has a good proportionate of different energy sources in its energy mix like coal, Natural gas, oil in nonrenewable categories and hydel power, solar energy and biomass in renewable energy categories. Even then, Pakistan is facing serious energy crisis. So, energy has become hot issue for researchers as well as policy makers. The nexus between the utilization of energy and growth of economy for the economy of Pakistan is investigated in many researches but the results are contradictory. Previous studies mainly focused on only two variables, that is, energy use and economic growth. But the economics theory considers the prices as main determinant of demand. Therefore, energy price is an important determinant of energy consumption and it must be considered while investigating relationship among the utilization of energy and growth of the economy.

The main gap in the previous research is the negligence of energy prices while investigating the causal relationship among utilization of energy and growth of the economy in case of Pakistan. Also, most of the studies considered only two variables, which may cause variable omission bias and bivariate biasness in the results. To reduce the bivariate biases in results, this study is conducted using trivariate time series model. To fill the research gap of previous studies energy prices are also considered in energy-growth nexus. The study will explore new dimensions for the nexus among the utilization of energy and growth of the economy in Pakistan and will also provide significant information to the policy maker. Gross Domestic Product Per capita (GDP per capita) in billion US dollars and per capita energy use kilogram of oil equivalent (Kgoe) are considered as indicator of economic growth and energy consumption respectively. Consumer price index calculated for 2005 as base year is used as proxy variable for energy prices (Aziz, 2011).

In this study, our main emphasis included the following:

- To investigate the long run along with short run association among the usage of energy, energy prices and growth of the economy
- To identify the direction of causality among the variables
- To propose some Policy implications and recommendations on the basis of results

Review of Literature

Numerous studies have carried on investigating the association among the utilization of energy and growth of an economy. The results of the studies show inconsistent and contradictory results about the association among the use of energy and growth of an economy. The results for some studies argue that utilization of energy does not have any impact on the growth of an economy and the relationship among these two variables is neutral. Contrarily, some studies have found significant association among the usage of energy and growth of an economy. Confliction in the findings of studies may be a result of variation in techniques and methodologies adopted for analysis, difference in there sources of the countries, difference among the chosen variables and difference in the data sets used for analysis. This section includes literature sighted by different researcher about the nexus among the usage of energy and growth of an economy; the econometric techniques used by the researchers, the empirical findings and important policy implications of the studies are also presented in this chapter.

Nguyen (1984) discussed Adams and Miovic’s formerly anticipated techniques in 1968 to calculate the amount of elasticity produced of constructive energy consumption. The author firstly found that procedural approach was quite doubtful. After that alternative approaches were proposed and stress was given on marginal rate of GDP. By using coefficients of thermal efficiency and data of OECD countries for the period 1959-1973, the author found that energy consumption go down from the higher values.

Masih and Masih (1996) investigated the fundamental connection between energy utilization and the economic growth by using Engle Granger Co-integration test in assistance of six Asian nations. The results instigated that no co-integration has been found between the utilization of energy and growth of the economy for Malaysia, Philippines and Singapore. However, significant co-integration for India, Indonesia and Pakistan has been anticipated. Blended results were observed for the association among the utilization of energy and growth of these countries; national income Granger caused energy use in case of Indonesia while converse results were observed in case of India and bidirectional causality was found in case of Pakistan.

Cheng (1999) applied Johansen co-integration test to assess the co-integration among energy spending, labor, economic growth and capital. No causality has been found between the utilization of energy and growth of the economy by the use of Granger causality method with the assistance of error correction model and co-integration. However, it has been anticipated that in both long and short periods of time, the causality executed from growth of the economy towards energy spending, while causality continuance from capital towards economic growth was found in short likewise in longer period of time.

Aqeel and Butt (2001) considered the association among the utilization of energy and development of the economy in case of Pakistan. Co-integration among the series of variables by co-integration test and causality by Granger's test were examined. The results confirmed the unidirectional causality form growth of the economy towards the utilization of energy. Growth in petroleum consumption was observed due to the growth of economy while no causal association was found in growth of the economy and consumption of natural gas. In power sector, consumption of electricity Granger caused the growth of the economy. The important policy implication of the study, on the basis of empirical findings suggested bringing improvement in energy sector and special attention should be given to electricity production and gas extraction. Energy conservation policies were suggested in case of oil consumption.

Chontanawat *et al*. (2006) had scrutinized the causal factor among the utilization of energy and growth of an economy for 30 OECD and 78 non-OECD developing countries. Equations and many variables were developed since to find out the differences and results. The result had two perspectives first one was usage of energy Granger caused the growth of economy in positive scenario and the second one is non OECD countries had adverse effect on the growth of economy due to insufficient recourses to cover up spending on energy consumption.

Chen *et al.* (2007) inspected the association among electricity use and growth of the economy focusing both panel and single of 10 recently industrializing Asian countries in longer and shorter period of time. The applied methodology results were varied from country to country but the main conclusion of this study was if the energy shortage and demand had fulfilled then more energy consumption was causing for more economic growth and productions as well.

Khan *et al.* (2008) examined the association among energy utilization, Real GDP, Capital, and Labor for the four countries in South Asia that were India, Bangladesh, Pakistan and Sri Lanka by using the data from 1972 to 2004. By implementing the Bound Testing Approach (BTA) to co-integration, a sturdy co-integration had been found among energy utilization, Real GDP, labor and capital for every country. The main focus of the research was to assess the energy performance in ornamental production in South Asian State. A helpful confirmation had been found by using the un-restricted error correction model for the confirmation of longer and shorter period causality among energy use and real GDP for every country. These results suggested that South Asian economies were highly energy dependent. However, implications of energy preservation may possibly be devised in a way that in those regions no unfavorable effect would be produced on the growth of economy by these policies.

Ghosh (2010) considered India to inspect the fundamental linkage between carbon emission and economic development by employing Johansen-Juselius's ARDL bound-testing approach in a multivariate structure by integrated supply of energy, employment and investment for the time duration (1971–2006). The aftereffects indicated the existence of bi-directional short-haul causality between them. Thus, in short-haul any attempt to trim down carbon emission can direct to plunge in national income. Moreover, uni-directional short-duration causality executed from economic development (ED) to energy supply, also energy supply towards carbon emission has been established.

Razzaqi*et al.* (2011) inspected the association among the utilization of energy and growth of the economy in D-8 countries. Co-integration was tested by the application of Johansen's test and for causality VECM and Granger's test of causality were implemented. Existence of co-integration approved the association among the variables for a longer period of time in the entire countries. The outcomes sustained Uni-directional or Bi-directional causality in D8 countries excluding Indonesia in short run and non-causality has been entrenched between these two variables.

Dedeoglu and Piskin (2014) reviewed the association among aggregated output per capita (GDP per capita) and utilization of energy. The study focused on the 15 former Soviet Union countries and is relevant for the period from 1992 to 2009.The following models were used for analysis; panel vector error correction model; panel co-integration tests and panel stationarity tests. The results confirmed that in the long term a unidirectional causal relationship exists among aggregated output per capita (GDP per capita) and utilization of energy, however in the shorter term, this was not the case. Furthermore, for countries that import oil and natural gas, a bi directional relationship was observed.

Rafindadi and Ozturk, (2015) inspected the relationship among utilization of natural gas and growth of the economy to check the effectiveness of 10th Malaysian Plan. To find out the relationship they used the data for the period 1971-2012. The variables included real aggregated output (real GDP), usage of per capital natural gas, real export per unit of population, per capital real stock and labor force from the total population. They implemented robust result, Bayer-Hanck co-integration, Johansen co-integration and ARDL test to find out the results. The results expressed that there is no relationship among utilization of natural gas and growth of the economy.

Materials and Methods

To investigate the impact of energy consumption on economic growth in presence of energy prices, the specified model is based on simple multivariate time series framework. The functional relationship among the variables can be specified in following form;

$$EG = f(EC, EP) \qquad (1)$$

Where EG represents the per capita Gross Domestic Production (GDP per capita), EC represents the per capita energy consumption (energy use per capita) and EP represents the energy prices (consumer price index, 2005 as a base year is used as proxy variable). For obtaining more stationary and linear behavior, natural logarithm of the variables is taken (Chaudhry *et al.* 2012). The econometric model in double logarithmic equation form is as follows;

$$LEG = \beta_0 + \beta_1 LEC + \beta_2 LEP + \mu \qquad (2)$$

Where LEG is the natural logarithm of GDP per capita, LEC is the natural logarithm of energy consumption per capita, LEP is the natural logarithm of energy prices and μ is the residual term. β_0 is intercept while β_1 and β_2 are the slope coefficients of energy consumption per capita and energy prices respectively.

This study is conducted to investigate the impact of energy consumption on economic growth of Pakistan. That is, whether energy consumption is prerequisite for economic growth or economic growth enhances the energy consumption. A number of studies has been conducted to investigate the causality between energy consumption and economic growth and obtained diverse results. The energy prices were not taken into account in the previous studies, this study is conducted to fill the gap by taking into account the energy prices. Time series econometric techniques are used to analyze the causality among economic growth, energy consumption and energy prices.

Granger causality test investigates the extent to which the change in lagged values of one variable explains the variations in the current value of other variable. For two variables X_t and Y_t, the possible results for Granger causality test will be; Y_t Granger causes X_t (unidirectional causality from Y_t to X_t), X_t Granger causes Y_t (unidirectional causality from X_t to Y_t), X_t Granger causes Y_t and Y_t Granger causes X_t (bidirectional causality between X_t and Y_t) or neither X_t Granger causes Y_t nor Y_t Granger causes X_t (no causality between X_t and Y_t). All the results are based on the assumption of stationary data (Gelo 2009). Granger causality test provides false results about the causal relation among the variables in case of non-stationary data (Cheng 1996).

Before applying the causality test, variables must be tested for stationarity and co-integration among them. The analysis consists of four steps. In the first step, the stationarity or order of integration of the variables is tested. Many unit root tests are available in econometrics to test the stationarity of the series. Augmented Dickey Fuller test (ADF) and Phillips Perron (PP) unit root test are among the most commonly used unit root tests. Both Augmented Dickey Fuller test (ADF) and Phillips Perron (PP) unit root test are used in this study with and without intercept (Dickey and Fuller, 1981; Phillips and Perron, 1988). The purpose of applying both ADF and PP test at the same time to the series is to get consistent results.

The null hypothesis for these tests is that the series has a unit root or series is non stationary. The criteria for unit root test is that if the calculated t-value in absolute term is greater than the critical value then the series has no unit root or it is stationary otherwise it has a unit root or series is non stationary. For unit root, consider the following equations;

Unit root including trend and constant,

$$\Delta Y_t = \beta_1 + \beta_2 t + \delta Y_{t-1} + \alpha \sum_{i=1}^{p} \Delta Y_{t-1} + \mu_t \quad (3)$$

Unit root without trend, constant only

$$\Delta Y_t = \beta_1 + \delta Y_{t-1} + \alpha \sum_{i=1}^{p} \Delta Y_{t-1} + \mu_t \quad (4)$$

In the above equations, Y is the variable need to be tested for unit root, Δ is the difference operator, p is the number of lagged terms and μ is residual term of white noise with zero mean and constant variance. α, β and δ are the parameters. In equation 3, t is the time trend. Variables under discussion will be tested for unit root by using the above equations.

Second step involves the appropriate lag selection for Vector Autoregressive (VAR) model or Vector Error Correction (VEC) model. Because when all the variables are stationary at their first difference either VAR or VEC model will be applied, it depends on co-integration among the series. To test co-integration, proper lag differences need to be selected. Likelihood Ratio (LR), Final Prediction Error (FPE), Akaike Information Criterion (AIC), Hannan and Quinn Information Criterion (HQIC) and Schwarz Bayesian Information Criterion (SBIC) tests are used for lag selection. Normally, lag is selected on the bases of majority then too AIC and FPE are more appropriate criterion for lag selection. The yardstick for lag selection is that in each criterion minimum value of the criterion will be considered to select an appropriate lag.

Third step is to investigate if there is any long run association among the variables or not. Long run association among economic growth, energy consumption and energy prices mean that the variables are integrated of order one, that is, I(1) but the linear combination of the variables is stationary at level, that is, series are co-integrated. Co-integrated series confirm the long run association of the variables and speed of adjustment to the equilibrium. In econometrics, many tests are available to investigate co-integration of the series like Engle and Granger (1987) test of co-integration, Johansen (1988) test of co-integration, Stock and Watson (1988) test for co-integration and Phillips and Ouliaris (1990) co-integration test. Johansen co-integration test is applied to test the long run relationship among the variables (Johansen, 1988; Johansen and Juselius, 1990). The reason for applying Johansen test of co-integration is that it treats all the variables as endogenous while testing the long run association among the variables.

There are two forms of Johansen's co-integration test: the trace statistic test and maximum eigen value test. In trace statistic test while investigating the existence of co-integration, null hypothesis implies that there is no co-integration and the alternative hypothesis implies at least one co-integration combination. In case of maximum eigenvalue test, the null hypothesis is the same but alternative hypothesis implies only one co-integrating combination.

Johansen co-integration test investigates the co-integrating vector among the series with null hypothesis that there is no co-integration among the series for rank zero (r=0). A decision criterion is that if the trace value or maximum eigenvalue statistics for Johansen test is greater than the critical value, the null hypothesis will be rejected at that significance level. On the basis of this criterion co-integration for higher ranks will be tested. The rejection of null hypothesis for rank zero will be an evidence for presence of co-integration among the series. If the variables are represented by X_t and all the variables are integrated of order one I(1) then the integrating vector give rise to the stationary variable and the co-integration equation for co-integrating vector r will be of the form;

$$\Delta X_t = c + \sum_{j=1}^{p} r_j \Delta X_{t-j} + \varepsilon_j \qquad (5)$$

On the conformation of co-integration among the series, Vector Error Correction Model (VECM) can be applied to the co-integrated series. Vector Error Correction Model (VECM) is used to determine the direction of causality between energy consumption and economic growth. Residuals of equilibrium regression are used to estimate VECM. The equations of VECM are;

$$\Delta EG_t = \alpha_1 + \sum_{i=1}^{p} \beta_{1i} \Delta EG_{t-1} + \sum_{i=1}^{p} \gamma_{1i} \Delta EC_{t-1} + \sum_{i=1}^{p} \varpi_{1i} \Delta EP_{t-1} + \theta_{1,1} ECT_{1,t-1} + \varepsilon_{1t} \qquad (6)$$

$$\Delta EC_t = \alpha_2 + \sum_{i=1}^{p} \beta_{2i} \Delta EG_{t-1} + \sum_{i=1}^{p} \gamma_{2i} \Delta EC_{t-1} + \sum_{i=1}^{p} \varpi_{2i} \Delta EP_{t-1} + \theta_{2,1} ECT_{1,t-1} + \varepsilon_{2t} \qquad (7)$$

$$\Delta EC_t = \alpha_3 + \sum_{i=1}^{p} \beta_{3i} \Delta EG_{t-1} + \sum_{i=1}^{p} \gamma_{3i} \Delta EC_{t-1} + \sum_{i=1}^{p} \varpi_{3i} \Delta EP_{t-1} + \theta_{3,1} ECT_{1,t-1} + \varepsilon_{3t} \qquad (8)$$

Where EG represents the GDP per capita, EC represents the energy consumption, EP represents the energy prices and Δ represents the first difference of the variable. Error correction term is represented by ECT_i and the speed of adjustment to the equilibrium is measured by the coefficient of ECT_i. α_i is the intercept and p is the lag length which is chosen by AIC and FPE lag selection criterion. Equation (6) is used to investigate the causality from energy consumption and energy prices to economic growth. Equation (7) is used to investigate the causality from economic growth and energy prices to energy consumption. Equation (8) is used to measure the causality from economic growth and energy consumption to energy prices.

In addition to the Granger causality under basic VAR test, VECM takes into account both short run and long run causation among the variables. The test of hypothesis for lagged coefficients of the variable indicates the short run causality between the variables while significant negative coefficient of ECT_i is an evidence for the long run causality running from independent variables to the dependent variable (Masih and Masih 1996). The short run Granger causality based on the lagged variables is investigated by using F-test or Wald χ^2 test with a null hypothesis that all the coefficients of lagged variables are zero. On the other hand, the long run causality is determined with a restriction on θ_i that it must be negative and significant.

Data

Annual time series data over the period 1971-2014 is used in this study. Starting year of the series is restricted due to the access to the data for energy use per capita. Data is obtained from World Development Indicators (WDI), BP Statistical Review of World Energy 2014 and Economic Surveys of Pakistan. Yearly data of energy use per capita in kilograms of oil equivalent (kgoe) is used as energy consumption per capita. Gross Domestic Product per capita (GDP per capita) denominated in current US Dollars is used as an indicator of economic growth. Consumer Price Index (CPI for 2005 as base year) is used as proxy variable to energy prices. Energy consumption is the aggregation of energy consumed in form of coal, oil, gas, hydroelectricity and nuclear energy.

Total primary energy consumption has increased more than 7 times in last 44 years from 1971 to 2014. From 1971 to 1974, no significant change in primary energy consumption is observed. Afterwards, approximately 7 percent annual increase in primary energy consumption is observed. Composition of oil and gas consumption in total energy use has been rising significantly since 1997 as the contribution of manufacturing sector increased in this year. The flow of energy use in million tonnes of oil equivalent (Mtoe) and Gross Domestic Production (GDP) in billion current US dollars is shown in the following diagram.

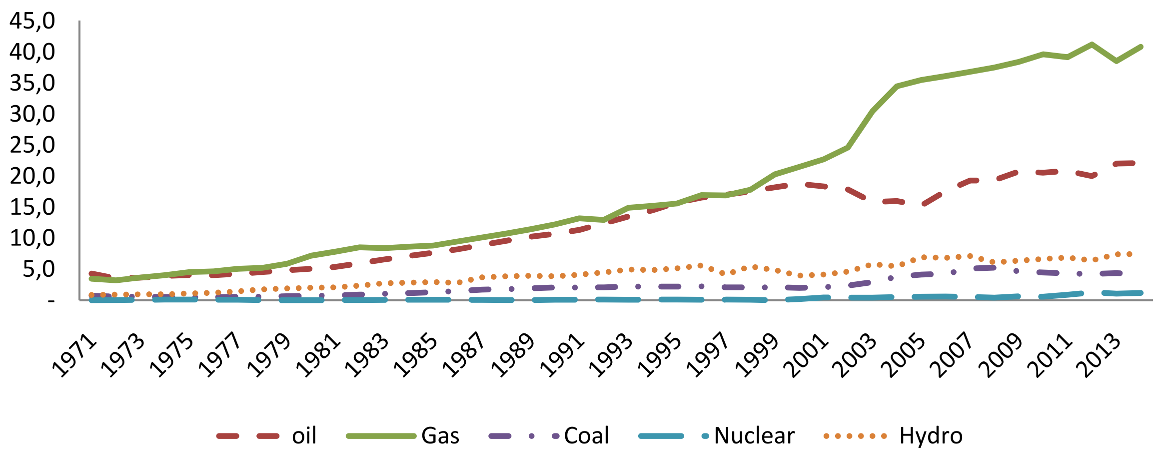

Figure 2: Energy consumption according to different forms of energy (Source: Energy data from BP Statistical Review of world energy over the period 1971-2014)

GDP is showing a declining trend for the period 1971-1974 due to war with India in 1971 and partition of East Pakistan (Bangladesh) put adverse effect on the growth of economy. Afterwards, GDP increased gradually at an average rate of 4.7 percent per year. GDP has risen at greater speed of an average rate of 6 percent per year during 2003 to 2007. Energy use is increasing gradually at an average rate of 4 percent per year. Energy use and GDP are divided with the population of the country in the corresponding year to get per capita energy use and per capita GDP to conduct this study. The circulation of per capita energy use and per capita GDP over time is shown in the following diagram.

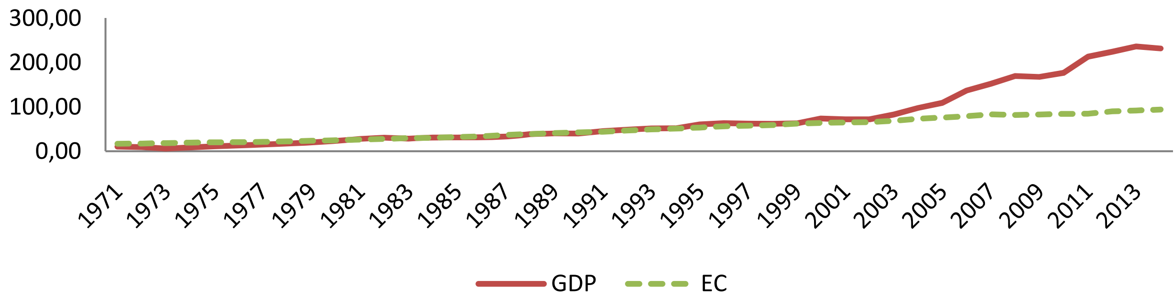

Figure 3. Flow of energy use and GDP (Source: Energy use and GDP data from WDI)

Results and Discussion

This study deals with the time series data that usually involves the problem non-stationarity in the data. So at the first step, the variables are tested for stationarity or the order of integration by the application of Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root tests. Table 1 shows the results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for economic growth at level considering constant only. The null hypothesis for the unit root test is that the series has a unit root or the series is non-stationary and decision rule is that the null hypothesis is rejected when test statistics is greater than the critical values.

The first column of table 1 reports the results of Augmented Dickey Fuller (ADF) unit root test and the second column reports the results of Phillips Perron (PP) unit root test. 1%, 5% and 10% critical values for Augmented Dickey Fuller (ADF) unit root test are -3.634, -2.952 and -2.610 respectively and the calculated value or test statistic is -0.557. Since the calculated value in absolute terms is smaller than the critical values, null hypothesis cannot be rejected. So, series is non stationary.

Table 1. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for GDP (Constant Only) at level

GDP (At Level)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-0.557	1%	-3.634	-0.035	1%	-3.628
	5%	-2.952		5%	-2.950
	10%	-2.610		10%	-2.608

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

To test the consistency in the results Phillips Perron (PP) unit root test is also applied. 1%, 5% and 10% critical values for Phillips Perron (PP) unit root test are -3.628, -2.950 and -2.608 and the calculated value or test statistic is -0.035. The absolute value of test statistics is smaller than the critical value at 1%, 5% and 10% levels of significance. Again the null hypothesis cannot be rejected. Both the tests suggest that series is non stationary at level.

Considering the trend term as expressed in the equation 3 in the previous chapter, the results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) test are reported in Table 2. The results for Augmented Dickey Fuller (ADF) show that the series is non-stationary at level form because the absolute value of test statistics is smaller than the critical value at 1%, 5% and 10% levels of significance. In case of Phillips Perron (PP) test, again the absolute value of test statistics is smaller than the critical value at 1%, 5% and 10% levels of significance. So, the null hypothesis that the series is non-stationary cannot be rejected rather we have to retain this null hypothesis. So, the data series of GDP is non-stationary at level form.

Table 2. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for GDP (Constant and Trend) at level

GDP (At Level)					
ADF Unit Root Test (Constant and Trend)			Phillips Perron Unit Root Test (Constant and Trend)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-2.479	1%	-4.224	-2.336	1%	-4.214
	5%	-3.532		5%	-3.528
	10%	-3.199		10%	-3.197

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

As the series is non stationary at level form, so we take the first difference and then apply the unit root tests. The results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test for differenced form are reported in Table 3. If the absolute value of test statistics is greater than the critical value of 5% level of significance, the null hypothesis that the series has a unit root will be rejected. The results for Augmented Dickey Fuller (ADF) show that the series is stationary at first difference because the absolute value of test statistics is greater than the critical value at 1%, 5% and 10% levels of significance and hence the null hypothesis that the series has a unit root will be rejected. The results for Phillips Perron (PP) unit root test are consistent to the results for Augmented Dickey Fuller (ADF) units root test. Therefore, the series is stationary in differenced form.

Table 3. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for GDP (Constant Only) at first difference

GDP (At First Difference)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-7.816***	1%	-3.641	-5.725***	1%	-3.634
	5%	-2.955		5%	-2.952
	10%	-2.611		10%	-2.610

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

Next variable is energy consumption that is tested for unit root. Considering the equation 4 in previous chapter for the unit root test, only constant term is included while applying Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test. The results are reported in Table 4. The critical values for Augmented Dickey Fuller (ADF) units root test at 1%, 5% and 10% level of significance are -3.634, -2.952 and -2.610 respectively. The absolute value of test statistic is smaller than the critical values. Therefore, the null hypothesis that the series has a unit root cannot be rejected at any chosen level of significance. Similarly, 1%, 5% and 10% critical values for Phillips Perron (PP) unit root test are -3.628, -2.950 and -2.608and the calculated value or test statistic is -0.035. The absolute value of test statistics is smaller than the critical value at 1%, 5% and 10% levels of significance. Again the null hypothesis cannot be rejected. Both the tests suggest that series is non-stationary at level.

Table 4. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Consumption (Constant Only) at level

Energy Consumption (At Level)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-1.365	1%	-3.634	-1.134	1%	-3.628
	5%	-2.952		5%	-2.950
	10%	-2.610		10%	-2.608

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

When trend term is considered in the equation for unit root test, the results varies. The results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test are reported in Table 5 when trend term is considered. 1%, 5% and 10% critical values for Augmented Dickey Fuller (ADF) units root test are -4.224, -3.532 and -3.199 respectively. The test statistic in absolute term is smaller than the critical values for all the significance levels. So, the null hypothesis of a unit root cannot be rejected.

Table 5. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Consumption (Constant and Trend) at level

Energy Consumption (At Level)					
ADF Unit Root Test (Constant and Trend)			Phillips Perron Unit Root Test (Constant and Trend)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-1.347	1%	-4.224	-1.306	1%	-4.214
	5%	-3.532		5%	-3.528
	10%	-3.199		10%	-3.197

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

Similarly, 1%, 5% and 10% critical values for Phillips Perron (PP) unit root test are -4.214, -3.528 and -3.197 respectively. The calculated value or test statistic is -1.306, which is smaller than the critical values in absolute terms. So, the null hypothesis of unit root test that the series is not stationary cannot be rejected in case of Phillips Perron (PP) unit root test. So, both the unit root tests show consistent results. Hence, the series is non-stationary at level.

Now we convert the data for energy consumption in differenced form and then unit root test is applied to the series. The results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test are reported in Table 6. Augmented Dickey Fuller (ADF) test results are presented in the first column. The critical value of 1%, 5% and 10% level of significance are -3.641, -2.955 and -2.611 respectively. The value of test statistic is -4.404 which is greater than the critical value of 1%, 5% and 10% level of significance in absolute terms. So, the null hypothesis that the series is non-stationary can be rejected at each level of significance. Similarly, the results for Phillips Perron (PP) test are shown in second column. The critical value of 1%, 5% and 10% level of significance are -3.634, -2.952 and -2.610 respectively. The calculated value of test statistic is -5.984 whichis greater than the critical value of 1%, 5% and 10% level of significance. So, the null hypothesis that the series is non-stationary can be rejected at each level of significance. Therefore, the stationary is stationary in differenced form.

Table 6. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Consumption (Constant Only) at first difference

Energy Consumption (At First Difference)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-4.404***	1%	-3.641	-5.984***	1%	-3.634
	5%	-2.955		5%	-2.952
	10%	-2.611		10%	-2.610

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

Table 7. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Prices (Constant Only) at level

Energy Prices (At Level)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-1.399	1%	-3.634	-1.194	1%	-3.628
	5%	-2.952		5%	-2.950
	10%	-2.610		10%	-2.608

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

The third variable considered in this study is energy prices. The time series data of Consumer Price index (CPI) is used as proxy variable for energy prices. To test the stationarity of the data, Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test are applied and results for unit root tests are reported in Table 7. In first column, 1%, 5% and 10% critical values for Augmented Dickey Fuller (ADF) test are -3.634, -2.952 and -2.610. The absolute value of test statistic is smaller than the critical value at any level of significance. Therefore, the null hypothesis of non-stationarity cannot be rejected. In second column, 1%, 5% and 10% critical values for-Phillips Perron (PP) test are -3.628, -2.950 and -2.608.The absolute value of test statistic is smaller than the critical value at any level of significance. Therefore, the null hypothesis of non-stationarity cannot be rejected.

Considering the equation 3 for unit root test that includes trend term as well, results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test are reported in Table 8. In first column, 1%, 5% and 10% critical values for Augmented Dickey Fuller (ADF) test are -4.224, -3.532 and-3.199 respectively. The test statistic in absolute terms is greater than the critical values, suggesting that series is stationary. On contrary, 1%, 5% and 10% critical values for Phillips Perron (PP) test are -4.214, -3.528 and-3.197 respectively. The absolute value of test statistic is smaller than the critical value of each significance level. Hence, the null hypothesis that series is non-stationary cannot be rejected. Most of the results are evident for non-stationarity of the series, so the series is considered non-stationary at level form.

Table 8. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Prices (Constant and Trend) at level

Energy Prices (At Level)					
ADF Unit Root Test (Constant and Trend)			Phillips Perron Unit Root Test (Constant and Trend)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-5.512***	1%	-4.224	-2.720	1%	-4.214
	5%	-3.532		5%	-3.528
	10%	-3.199		10%	-3.197

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

Table 9. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test for Energy Prices (Constant Only) at first difference

Energy Prices (At First Difference)					
ADF Unit Root Test (Constant Only)			Phillips Perron Unit Root Test (Constant Only)		
Test Statistics	Significance Value	Critical Value	Test Statistics	Significance Value	Critical Value
-3.757	1%	-3.641	-3.455	1%	-3.634
	5%	-2.955		5%	-2.952
	10%	-2.611		10%	-2.610

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

For further analysis, first difference of the series is taken and unit root tests are applied to test the stationarity of the data. Results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test are reported in Table 9.

In first column, 1%, 5% and 10% critical values for Augmented Dickey Fuller (ADF) test are -3.641, -2.955 and -2.611. The absolute value of test statistic is greater than the critical value at any level of significance. Therefore, the null hypothesis of non-stationarity is rejected. In second column, 1%, 5% and 10% critical values for Phillips Perron (PP) test are -3.634, -2.952 and -2.610.The absolute value of test statistic is greater than the critical value at any level of significance. Therefore, the null hypothesis of non-stationarity is rejected. Hence, the series is stationary at first difference.

Summary of the above results for the unit root tests is presented in the following table. Column 1 and column 2 of Table 10 report the results for Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test respectively.

Table 10. Results for Augmented Dickey Fuller (ADF) and Phillips Perron (PP) unit root test

	Augmented Dickey Fuller Test		**Phillips-Perron Test**	
	Level			
	Intercept	**Intercept and Trend**	**Intercept**	**Intercept and Trend**
LEG	-0.557 (0.8804)	-2.479 (0.3387)	-0.035 (0.9556)	-2.336 (0.4141)
LEC	-1.365 (0.5990)	-1.347 (0.8758)	-1.134 (0.7014)	-1.306 (0.8865)
LEP	-1.399 (0.5828)	-5.512 *** (0.0000)	-1.194 (0.6762)	-2.720 (0.2280)
	First Difference			
	Intercept	**Intercept and Trend**	**Intercept**	**Intercept and Trend**
D_EG	-7.816 *** (0.0000)	-7.686 *** (0.0000)	-5.725 *** (0.0000)	-5.619 *** (0.0000)
D_EC	-4.404 *** (0.0003)	-4.548 *** (0.0013)	-5.984 *** (0.0000)	-6.110 *** (0.0000)
D_EP	-3.757 *** (0.0034)	-3.611 ** (0.0289)	-3.455 *** (0.0092)	-3.582 ** (0.0314)

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

The null hypothesis for both Augmented Dickey Fuller (ADF) units root test and Phillips Perron (PP) unit root test is that there exist unit root in the series or series is non-stationary. The decision criteria is that if the test statistic is greater than the critical value then thee null hypothesis will be rejected and series is considered to be stationary and vice versa. The results show that the null hypothesis cannot be rejected for the variables in their level form. It indicates that economic growth, energy consumption and energy prices are non-stationary at level. On taking first difference, all the variables become stationary at less than 1% level of significance. Hence, all the variables are integrated of order one that is I (1).

As all the variables are integrated of order one, the next step is to test if there exist the long run relationship among the variables or if the variables are co-integrated by applying Johansen's test of co-integration. Before applying Johansen co-integration test, it is necessary to choose appropriate lag difference. The results for Likelihood Ratio (LR), Final Prediction Error (FPE) and Akaike Information Criterion (AIC) of lag selection under Vector Autoregressive (VAR) model and Vector Error Correction (VEC) model are summarized in Table 11. Four lags difference is suggested by all the three criterions. Johansen co-integration test can be applied using the lag difference suggested by these criterions.

Table 11. Results for Likelihood Ratio (LR), Final Prediction Error (FPE) and Akaike Information Criterion (AIC)

Lag	LR	FPE	AIC
0	-	0.000032	-1.85059
1	393.85	2.6e-09	-11.2469
2	38.002	1.6e-09	-11.747
3	20.187	1.6e-09	-11.8017
4	20.787*	1.5e-09*	-11.8713*

Source: Results generated by STATA 12

All the variables are integrated of same order; therefore co-integration test is applied to test the long run association among economic growth, energy consumption and energy prices. The results for Johansen co-integration test with four lags difference are reported in Table 12. The null hypothesis for rank 0 is that there is no co-integration among economic growth, energy consumption and energy prices or the variables are not associated to each other in long run. Trace statistics and maximum eigenvalue statistics for Johansen co-integration test are compared with corresponding 5% critical values. The null hypothesis for rank 0 is rejected because the calculated value is greater than the critical value. The results for Johansen co-integration test confirm that economic growth, energy consumption and energy prices are co-integrated and are associated to each other in long run.

Table 12. Results for Johansen co-integration test

Maximum Rank	Trace Statistics	5% Critical Value	Max Statistics	5% Critical Value
0	47.4544	29.68	32.8883	20.97
1	14.5661*	15.41	9.9018*	14.07
2	4.6643	3.76	4.6643	3.76
3	-	-	-	-

Source: Results generated by STATA 12

Since the stationarity test provides the evidence that all the variable under discussion are integrated of order one; that is, I(1) and co-integration among the series is confirmed by Johansen co-integration test which is an evidence for long run association of the variables. It means there is at least unidirectional causality either from energy consumption to economic growth or from economic growth to energy consumption. Vector Error Correction Model (VECM) is used to analyze the direction of causality for co-integrated I(1) series. In addition to the Granger causality test under standard Vector Autoregressive (VAR) test, error correction term in Vector Error Correction Model (VECM) provides additional channel to investigate long run causality among the variables. The results for Granger causality under Vector Error Correction Model (VECM) are presented in Table 13.

Long run causality is investigated on the basis of error correction term and short run causality is examined by using lagged values of independent variables through F-statistics assuming that all the slope coefficients are zero. The results in Table 13 indicates that economic growth Granger causes energy consumption and there is unidirectional causality running from economic growth to energy consumption in both short run and long run. The findings of this study are similar to the findings of Ahmad (2012) for Pakistan, Ang (2008) for Malaysia, Masih and Masih (1998) for Indonesia, Oh and Lee (2004) for Korea and Yoo (2006) for Indonesia.

Table 13. Results for Vector Error Correction Model

Dependent Variable	**Source of Causation (Independent variables)**						
	Short Run			**Long Run**	**Strong Causality**		
	ΔLEG	**ΔLEC**	**ΔLEP**	**ECT**	**ΔLEG, ECT**	**ΔLEC, ECT**	**ΔLEP, ECT**
ΔLEG	-	4.5391 (0.4155)	-1.4529 (0.1635)	-0.2204* (0.096)	-	-0.0021 (0.860)	-0.1981 (0.047)
ΔLEC	0.2203*** (0.0009)	-	-0.3201 (0.4131)	-0.0202 (0.484)	0.0048** (0.030)	-	-0.0834* (0.070)
ΔLEP	-0.6883 (0.3810)	-3.124** (0.0132)	-	0.1685*** (0.000)	0.0418 (0.308)	0.1304* (0.076)	-

Source: Results generated by STATA 12

Note: The numeric values in parentheses are p-values. (***), (**) and (*) indicate 1%, 5% and 10% level of significance respectively

Discussing about the short run results in table 13, in economic growth equation, neither the lagged values of energy consumption nor the lagged values of energy prices have significant effect on economic growth. In energy consumption equation, the coefficient of lagged values of economic growth has significant effect at less than 1 percent significance level but the lagged values of energy prices do not have significant effect on energy consumption in short run. The lagged values of energy consumption have significant effect on energy prices in last equation but the lagged values of economic growth do not significantly affect the energy prices in short run. Therefore, unidirectional causality in short run is found from economic growth to energy consumption and energy consumption to energy prices, whereas energy prices have neutral relationship with both energy consumption and economic growth. It means that an increase in growth activities enhances the demand for energy in short run which influence the energy prices.

The probability values for the coefficients of ECTs provide the evidence for long run causality among the variables. Coefficient of ECT is significant in both income and price equation. It means that economic growth and energy prices interact with each other in short run to reinstate the long run equilibrium to any change due to energy consumption. Discussing about the last three columns, energy consumption has a significant impact on energy prices in long run. Also, both economic growth and energy prices have significant impact on energy consumption.

On the basis of results and above discussion, it is concluded that unidirectional causality is found from economic growth to energy consumption in short run as well as in long run. For energy consumption and energy prices, unidirectional causality is found from energy consumption to energy prices in short run and bidirectional causality between energy consumption and energy prices is observed in long run. With respect to the previous studies, the results of the study are consistent to

Kraft and Kraft (1978) for USA, Yu and Choi (1985) for South Korea, Masih and Masih (1996) for Indonesia, Soytas and Sari (2003) for South Korea, Odhiambo (2010) for Congo.

Conclusions and Policy Implications

This study is conducted to investigate the impact of energy consumption on economic growth of Pakistan on the basis of time series data over the period 1971-2014. To avert the biases in the results of bivariate analysis of causal relationship, energy prices are also included in this study as an additional variable for the causal association between energy consumption and economic growth. More endogenous variables in the study provide additional channels for adjustment to the long run equilibrium.

Same order of integration in all the variables is confirmed by application of unit root test. Presence of co-integrating vector among the variables by Johansen's co-integration test confirms the long run association among the variables. The results for Granger causality test under Vector Error Correction Model (VECM) report the unidirectional causality from economic growth to energy consumption in short run as well as in long run. The results also affirm the unidirectional causality from energy consumption to energy prices in short run and bidirectional causality between energy consumption and energy prices in long run.

This study reports that growth in the country stimulates the demand for energy that affects the energy prices. The results are helpful to the policy makers to understand the association among energy consumption, energy prices and economic growth then formulate esteemed policies about the energy sector of Pakistan. As economic growth Granger causes energy consumption, it recommends energy conservation policies should be adopted. The policy may have negligible or no adverse effects on the growth of the country. This policy is also helpful to control the energy prices and hence inflation, to rescue the economy from adverse price shocks. Although, Pakistan is facing serious energy crisis but still there are some policy implications are available to conserve the energy. For example, energy can be conserved by advancing the standard clock by an hour in summer, imposing the time limits in markets in shopping centers and by restricting the night working shift in industries.

Although, this study is conducted to bridge up the gap in the previous researches by considering a trivariate model to overcome bivariate biasness and by considering energy prices, an important variable for energy-growth nexus, still there are some weaknesses. Some important variables and determinants of energy-growth nexus like capital, labour, trade openness, foreign direct investment etc. are still neglected. Also, energy consumption is not disaggregate levels; like effect of oil consumption on GDP, effect of coal consumption on GDP, effect of natural gas consumption on GDP, effect of electricity consumption on GDP and relationship between renewable energy and GDP is also not considered in this study.

Environmental issues are the main concern in the recent studies. Emissions from the consumption of different forms of energy and emissions of Green House Gases (GHG) are ruining the environment and causing serious health issues. This study also neglected the environmental issues related to gaseous emissions, which are degrading the environment. The emissions are another important aspect that is not discussed while investigating the relationship between the utilization of energy and growth of the economy. The role of renewable and non-renewable energy consumption in growth of the economy and their relationship with emissions needs to be considered to devise effective policy measures to control environmental degradation.

The results derived from this study have recommended remarkable policy implications for the energy sector of the economy but still this issue need consideration in future research. As a suggestion for future researches on the nexus between energy consumption and economic growth, one may consider multivariate model by addition of variables like labor force, capital formation, carbon dioxide emissions etc. in the model and may also consider both aggregated and disaggregated levels of energy to investigate its relationship with growth of the economy as well as the relationship of different forms of energy with carbon dioxide emissions.

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