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Long Run Relationship between Energy Efficiency and Economic Growth in Pakistan: Time Series Data Analysis

Tahir Mahmood and Faiza Kanwal[1]

Abstract

This study explores the nature of relationship between energy efficiency, measured by energy intensity (energy consumption to GDP ratio) and the level of economic activity, measured by GDP in Pakistan during 1980-2016. This study also analyzes the relationship between sectoral shares and energy efficiency. We used Error Correction Model (ECM) for empirical analysis to tests the existence of a long-term relationship between the energy intensity and GDP while using this model to capture the Granger causality between variables. Results of Johansen's co-integration show that causality exists at least in one direction. Results of ECM predict the existence of unidirectional causality from GDP to energy intensity. These findings support conservation hypothesis on the basis of unidirectional causality running from output to energy efficiency. It is further observed that energy intensity in Pakistan is expected to increase further in the light of growing shares of industrial and services sectors in the GDP.

Keywords: Energy Efficiency, Energy Intensity, Economic Growth, Sectoral Output.

JEL Classification: O4, Q00, Q4

1. Introduction

Energy is the driving force of life on earth. Its availability and utilization is essential for almost all major economic activities. The insufficiency of energy influences the lives of the masses in various forms; from the wheels running on the roads, operation theatres in hospitals, laboratories, educational institutions, private businesses, and industries like manufacturing and agriculture. Precipitous fall in the industrial output, thin margins in the local and international markets and shaken confidence of the industrialists in some developing countries are the outcomes of power breakdowns and intense power outages.

[1] The authors are Assistant Professor at School of Economics, Quaid-i-Azam University and Research Assistant at Centre for Peace and Development Initiatives, Islamabad, respectively. Authors are thankful and give special gratitude to Higher Education Commission of Pakistan (HEC) for financial assistant. Corresponding author's email: tamahmood@qau.edu.pk

During the past few decades energy has emerged as a critical input to economic growth. Although business and financial economists have noted the importance of energy, especially energy prices in their analysis (Poveda and Martinez, 2011), the theories of economic growth continues to give little importance to the impact of energy on economic growth (Dizdarevic and Zikovic, 2010). Most of the studies on the role of energy in economic growth are empirical in nature. For example, Kraft and Kraft (1978) found causality running from GNP to energy consumption. This study is conducted for the USA for the period 1947 to 1974. Huang et al. (2008) divided the sample of 82 countries into groups for causality analysis. The study found no causality between economic growth and energy consumption for the low income countries, a positive causality from economic growth to energy consumption for middle income countries and a negative causality from economic growth to energy consumption for rich countries. The results indicate that energy efficiency has improved in high income countries, thus improving the environment. A bi-directional positive relationship was discovered when data for all countries were used as a whole. Martinot (1998) described that there is huge potential in Russia for the improvement in energy efficiency but incentives in infrastructure and human resource capabilities are the main obstacles. Painuly et al. (2003) stated that there is tremendous potential in developing countries to increase energy efficiency.

Energy efficiency refers to the effective and efficient utilization of the available energy resources. Energy intensity is often used as a proxy of energy efficiency of an economy. Energy intensity, usually defined as energy use per unit of GDP, indicates the total energy being used to boost economic and social activity, (Poveda and Martinez, 2011). The more intense is the energy usage, the higher is the cost of converting raw material into final product, resulting in meager economic performance, deteriorated environment and low standards of living. In the existing literature the relationship between energy consumption and economic growth is analyzed through four hypotheses: growth hypothesis, feedback hypothesis, conservation hypothesis and neutrality hypothesis (Yildirim, et al., 2014).

Most of the studies on the relationship between energy use and economic growth focus on developed countries, particularly the European ones. Developed countries are rich with stable populations and, therefore, they tend to have energy efficiency that is improving constantly. On the other hand, developing countries are generally poor and face high population growth rates and limited availability of energy. Their resources are too limited to develop better technology and afford energy conserving environment. Hence their energy intensities are unfavorable, showing no systematic improvement over time.

The empirical evidence on the relationship between energy consumption and economic growth is mixed and mostly inconclusive. Nilsson (1993) evaluated energy intensity trends for 31 countries for the period 1950 to 1988 and found that energy intensity has decreased for about 50% of the countries under consideration. A panel analysis conducted by Lee (2005) for 18 developing countries clearly supports the short-run and long-run causality running from energy consumption to GDP. Hou (2009) studied the relationship between energy consumption and economic growth in China from the years 1953 to 2006. Various causality tests applied in the study confirm the existence of bi-directional causality between energy consumption and economic growth.

Khan and Qayyum (2008) inspected empirically the association between real GDP and energy consumption in Bangladesh, India, Pakistan and Sri Lanka. The results favor unidirectional causality from energy consumption to GDP in each country both in short and long run. The study reasoned that being energy dependent economies, shortage in energy may retard growth in these South Asian countries. Therefore, strong policies for the development of energy sector need to be adopted. Paul and Bhattacharya (2004) applied Engle- Granger co-integration on Indian data and found that a two-way causality exists between energy consumption and economic growth. In another India-specific study, Adjaye (2000) concluded that the energy consumption has significant impact on GDP growth rate in the long run.

Pakistan being a developing country has a major focus on GDP growth rate since independence. But in recent years the country has experienced a serious setback on economic growth, one of the reasons being severe crisis in the energy sector. The scarcity of energy, particularly electricity and natural gas, is considered to be one of the major reasons of the downfall in the GDP growth rate of the country from 3.8% during 2000-01 to 2007-08 to 2.4% during 2008-09 to 2013-14. The energy shortage in Pakistan is led by quite a few reasons, some of which may include the falling gas production, and 80% dependency on oil and gas (Pakistan Economic Survey 2012-13).

In a detailed study for Pakistan, Jamil and Ahmad (2010) found strong evidence for the existence of unidirectional causality from economic activity to electricity consumption at aggregate level as well as in major sectors of the economy. In a later study, Jamil and Ahmad (2011) further found that electricity demand is quite elastic with respect to the level of economic activity both at the aggregate and sectoral levels.

In a more recent study by Mahmood et al. (2014) revealed that the electricity requirements in Pakistan will grow to three times by the year 2050. The empirical analysis indicates that high economic growth can be achieved with expansion in energy consumption and its sources whereas the shortage in energy may retard the growth. The study suggests using alternative energy sources and multi-directional policies to achieve high economic growth rate. The study suggests that, it is quite difficult for Pakistan to increase its growth by making efficient use of energy resources. Although some policies related to energy conservation in Pakistan have been implemented since 2008, yet Pakistan has been observing a high rate of energy intensity.

We need to re-examine the causal relationship between the energy efficiency and GDP in short as well as in long run in order to gain better understanding of the sustainability of economic development in the wake of possibly unsustainable energy requirements. It is also important to note that the economy of Pakistan has undergone a rapid change in its structure during the past few decades. In particular, while the share of agriculture in GDP has declined from about 56% in 1959-60 to 25% in 2015-16, the share of services has increased from 38% to 58% during the same period. It would be interesting also to draw implications of this changing structure of economy for energy efficiency.

The present study is undertaken to address two questions. First, what is the nature of (direction) of causal relationship between energy intensity and GDP in short and in long run? The second question that this study addresses is how the energy intensity is expected to change in the light of changing shares of the major economic sectors to GDP. In this study, we use energy intensity as proxy for energy efficiency. Energy intensity is often used as a proxy of energy efficiency of an economy (Poveda and Martinez, 2011). . High energy intensity implies low energy efficiency

In order to find the long run and short run causalities, we apply Johansen's co-integration test and Error Correction Model (ECM). Result of Johansen's co-integration shows the long-run equilibrium relationship between the energy intensity and GDP. Therefore, Granger causality exists between them in at least one direction. The results from ECM show that a unidirectional causality runs from output to energy efficiency. This study also explores the relationship between sectoral shares and energy intensity. Study predicts positive and statistically significant relationship between sectoral shares and energy intensity.

The study is organized as follows. Section 2 presents the models to be analyzed. Section 3 presents the model and estimation procedure. Section 3 discusses the data set and variables construction. Section 4 presents the results, while section 5 concludes the study.

2. Models and Estimation Procedure

Since the oil price hikes in 1970s, economists have started to consider energy as an important factor in the production process (Ayres et al. 2013) and Pokrovski, (2003). Although one expects that under cost minimization framework energy consumption would have positive relationship with output, there is no prior basis to predict the relationship of energy efficiency with output. If energy input forms a fixed relationship with output, energy intensity will be independent of output. A sufficient, though not necessarily, condition for this to happen is that production function is subject to constant returns to scale. On the other hand, energy intensity may increase or decrease with output depending on how the production technology changes with the pace of economic growth. In practice, the nature of relationship between energy intensity and output is an empirical matter. A common practice to analyze the relationship between energy intensity and output is to specify a relationship like the following one.

$$\ln EI_t = \alpha_0 + \alpha_1 \ln Y_t + \varepsilon_t \qquad (1)$$

Here, EI_t is energy intensity at time t, Y_t is gross domestic product at time t and ln denotes natural logarithm. The parameter α_1 measures the dependency of energy intensity on output. The possible causal relationship between energy intensity and GDP needs a specific analysis that gives role to evident two-way predictability. In order to capture the long run relationship between energy intensity and gross domestic production, we use Vector Error Correction model for empirical analysis to tests the existence of a long-term relationship between the energy intensity and GDP while using the this model to capture the Granger causality between variables. We propose following three-step. First, we need to know the order of integration of energy intensity and GDP, co-integration tests valid if both the variables have the same order of integration. Tests by Fisher-ADF and PP-tests by Maddala and Choi (1999) are used to find the order of integration of the variables.

If both series have a same order on integration, in second step, the Johansen maximum likelihood method is used to test the co-integration relationship between the energy intensity and GDP in Equation (1), see Johansen and Juelius (1990). If energy intensity and GDP have co-integrating relationships, OLS method of estimation is applied to estimate Equation (1). The existence of co-integration indicates that there are long-run equilibrium relationships between the energy intensity and GDP. This also implies that Granger causality valid between them in at least one direction (Oxley and Greasley, 2008).

Third, if all the non-stationary series are I(1) and co-integrating, the error correction model (ECM) is used in order to correct the disequilibrium in long run, which is captured by the error-correction term (EC). We used following ECM in order to test the long-run and short-run causality among the energy intensity and GDP.

$$\Delta \ln EI_t = \beta_{10} + \sum_{i=1}^{m1} \beta_{11i} \Delta \ln EI_{t-i} + \sum_{i=1}^{k1} \beta_{12i} \Delta \ln Y_{t-i} + \theta_1 EC_{t-1} + \varepsilon_{1t} \quad (2a)$$

$$\Delta \ln Y_t = \beta_0 + \sum_{i=1}^{m2} \beta_{21i} \Delta \ln Y_{t-i} + \sum_{i=1}^{k2} \beta_{22i} \Delta \ln EI_{t-i} + \theta_2 EC_{t-1} + \varepsilon_{2t} \quad (2b)$$

Where

$$EC_t = \ln EI_t - \hat{\alpha}_0 - \hat{\alpha}_1 \ln Y_t \quad (3)$$

The coefficients with the summation signs corresponds to the short run dynamics of variables. Whereas, α_o is intercept in the equation, while, u_t reveals white noise process. We use Schwarz Bayesian Criteria (SBC) and Akaike Information Criteria (AIC) for the selection of optimal lags, where m and n reveal maximum numbers of lags of the variables in both equations.

Here, Equation is derived from the long-term co-integration relationship described in Equation (1). The sign Δ is the first-difference operator, the optimum lag lengths n_i and k_i are determined on the basis of Akaike's information criteria (AIC); and μ_{it} are the serially uncorrelated error terms. The parameter θ_1 and θ_2 measure the speed of adjustment at which the values of $\ln EI$ and $\ln Y$ come back to long-term equilibrium levels, once $\ln EI$ and $\ln Y$ violate the long-run equilibrium relationship. The negative sign of the estimated coefficients of error correction term (EC) show the speed of adjustment or speed of convergence toward long run equilibrium. The error correction models (ECM) represented by Equation (2) includes the lags of dependent, lag of previous disequilibrium term EC_{t-1}. The coefficients with the summation signs corresponds to the short run dynamics of variables. This specification can test the short-run and long-run causality among co-integrated variables.

Structural changes in an economy may also affect energy demand and energy efficiency. When a country develops it generally becomes more service oriented. Service sector is less energy demanding as compared to industrial sector. Therefore, energy intensity is expected to decline due to transformation of economy from industrial sector into services sector. It is widely believed that a large services sector reduces energy intensity in the long run (Bjork, 1999; Wolff, 1985b; Baumol et al., 1985; Wilber, 2002).

According to Panayotou (1993) in the initial stage of development, all the resources such as capital, labor and energy shift from agriculture sector into industrial sector. While in the final stage of development these resources shift from the industrial sectors to services sector. Therefore, in early stage of development, energy intensity increases and it decreases in the later stages of economic development. In the light of the above discussion, we estimate following model by OLS.

$$\Delta \ln EI_t = \alpha_0 + \sum_{i=1}^{m} \alpha_{1i} \Delta \ln EI_{t-i} + \sum_{i=1}^{n} \alpha_{2i} \Delta \ln agr_{t-i} + \sum_{i=1}^{p} \alpha_{3i} \Delta \ln ind_{t-i} + \sum_{i=1}^{k} \alpha_{4i} \Delta \ln ser_{t-1} + \mu_t \quad (4)$$

The variables, agr_t, ind_t and ser_t are the shares of agriculture, industry and services sectors in GDP , respectively. It is expected that with the increase in services sector's shares in output aggregate energy intensity will decline although Stern (2004) has noted that the energy consumption of this sector has increased in Europe. On the other hand, industrial and agricultural growth is supposed to be the backbone of economic development for almost all countries in the world. For the developing world, intensive use of the natural resources and energy resources is required to expedite the economic growth. Such a growth can be achieved at the cost of environmental degradation which is not desirable. Thus we may expect energy intensity to increase with the increase in the shares of these sectors.

3. Variables Specification and Data Sources

This study uses data on energy intensity, GDP (constant 2010 PPP international $), share of agriculture sector, share of industrial sector and share of services sector as percentage of GDP. Data on these variables are obtained from the World Bank Development Indicators from 1985 to 2016. The variables are defined as follows.

GDP is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. (Data source: World Bank national accounts data and OECD National Accounts data files).

Energy consumption is the sum of total energy consumed by all the sectors of the economy and is measured in BTU. The sectors included in this variable are; Domestic, industry, agriculture, commercial transport and government sectors. So final energy consumption (EC) calculates total energy consumed in all sectors of economy and from all sources (from aviation fuel to electricity and coal) in one unit. Data Source is American Energy Administration. The data on energy intensity are taken from the US Energy Information Administration. The variable is calculated by dividing the data on total primary energy consumption in quadrillion British thermal units by the gross domestic product (GDP). Gross domestic product is measured by GDP at PPP (constant 2010 international $). The share of industrial sector in output is the value added of industrial sector as a percentage of GDP. The share of services sector in output is the value added of services sector as a percentage of GDP. The share of agricultural sector in output is the value added of agriculture sector as a percentage of GDP. Time period of the study is 1980-2016.

4. Results and Discussion

The results in Table 1 are obtained from the estimation of Equation (1). Results show the impacts of GDP on energy intensity in the long run. The coefficient of gross domestic product is 0.019 which is positive and it is statistically significant at 1%. This implies that an increase of 1% in GDP will increase energy intensity, on average by 0.19% in long run. This finding is valid, if both series are integrated of same order. Following the procedure describes in section 3, GDP and energy intensity series are tested for the existence of unit root.

Table 1: Results for Long Run Relationship

Dep. Var.	$\ln Y_t$	**Intercept**	**Adj.** R^2	**JB**	**P-value**
$\ln EI_t$	-0.19*** (-7.35)	4.05** (6.85)	0.70	1.87	0.37

Note: ***, **, and * denote rejection of null hypothesis at 1, 5 and 10 % level of significance and figures in parenthesis indicate t-statistics.

Results is Table 2 show both energy intensity and GDP series are non-stationary and their order of integration is same (i.e. I(1)). Therefore, we apply

Johansen's co-integration test to find the long run or co-integrating relationship between energy intensity and GDP and results are mention in Table 3.

Table 2: Unit Root Test Results

Variables	ADF Test Stat	PP Test Stat	Conclusion
Tests applied at Level			
$\ln EI_t$	1.87 (0.99)	1.99 (0.99)	non stationary series
$\ln Y_t$	0.67 (0.98)	-0.17 (0.92)	Non-stationary series
Tests applied at First Difference			
$\ln EI_t$	-3.80 (0.008)***	-3.90 (0.006)***	stationary series
$\ln Y_t$	-3.12 (0.03)**	-3.23 (0.02)**	stationary series

Note: We mention p-value in brackets. ***, **, and * denote rejection of null hypothesis at 1, 5 and 10 % level of significance

Table 3: Results of Johansen's Co-integration Test

Eigenvalue	Trace Stat.	Max Eigen. Stat.	Number of co-integrations
0.649	16.08* (15.50)	15.80* (14.30)	None
0.112	0.25 (3.84)	0.259 (3.84)	At most 1

Note: The optimal lag lengths are selected using AIC. * indicates the rejection of a null hypothesis at 5% level of significance

The Johansen co-integration test shows the existence of long-run equilibrium relationship between energy intensity a 1% increase in the growth of GDP will decrease the growth of energy intensity by 0.19% in the long run. This suggests that economic growth has a negative influence on energy effeciency. Co-integration shows that causality exists at least in one direction. But it does not tells us the direction of relationship. Therefore, in order to find the direction of causality, we apply OLS on VECM mentioned in Equation 2(a) and 2(b). The short-run $\chi 2$-statistics, long-run t-statistics and joint F-statistics for Equation 2(a) and 2(b) are reported in Table 4. Results show that unidirectional causality runs from GDP to energy intensity. That is, increasing energy intensity is the outcome of economic growth rather than a means to achieve better growth targets. This obviously means that as GDP grows, energy effeciency will continue to decrease as well. Since economic growth cannot be compromised, in order to conserve energy deliberate efforts will be needed that tend to use relatively less energy intensive techniques.

Table 4: Long Run and Short Run Causality between Energy Intensity and GDP Results

(T = 36, 1980–2016, and HCSE t-values)

	OLS Equation 2(a) Dep. Var. $\Delta \ln EI_t$ Lag length m = 2	**OLS Equation 2(b)** Dep. Var. $\Delta \ln Y_t$ Lag length m = 2
Variable	**Coefficient**	**Coefficient**
$\Delta \ln EI_{t-1}$	0.051*** (0.000)	0.12 (0.95)
$\Delta \ln EI_{t-2}$	0.029** (0.03)	0.13 (0.61)
$\Delta \ln Y_{t-1}$	0.073* (0.06)	0.402 (0.06)
$\Delta \ln Y_{t-2}$	0.073* (0.06)	0.402 (0.06)
EC_{t-1}	-0.06*** (0.013)	-0.03* (0.09)
No of Obs.	34	34
R^2	0.58	0.68
D.W. Stat.	2.65	2.97

Note: We mention probability p-value in brackets. ***, **, and * denote rejection of null hypothesis at 1, 5 and 10 % level of significance

These results are consistent with those obtained in an earlier study by Jamil and Ahmad (2010) for Pakistan, whcih also supports conservation hypothesis while focusing mainly on electricity consumption rather than all forms of energy. The results are also in agreement with the findings of Huang et al. (2008) for poor countries. In long-run dynamics, the coefficient of the EC term is statistically significant with a negative sign in equation 2(a) and 2(b), this implies that a change in GDP is expected to affect the energy intensity through a feedback system. When business cycles occur in the system, energy intensity makes a short-run adjustment to restore the long-run equilibrium.

The economic growth stimulates energy consumption in developing countries. Therefore, one way causality which runs from economic growth to energy consumption implies energy conservation. The structural changes could be a channel through which an economy may also affect energy consumption and energy efficiency. When a country develops it generally becomes more industrial and service oriented. Service sector is less energy intensive as compared to industrial sector. Therefore, energy efficiency is expected to decline due to transformation of economy from agriculture to industrial sector. Another hand the energy efficiency is expected to improve due to transformation of economy from industrial sector into services sector. It is widely believed that a large services sector reduces energy intensity in the long run (see, Bjork 1999, Baumol et al. 1985).

Table 5: Results for Energy Intensity Sectoral Shares

(T = 36, 1980–2016, and HCSE t-values)

OLS Results Equation (4) with m=2, Dependent variable $\Delta \ln EI_t$	
Variable	**Coefficient**
$\Delta \ln EI_{t-1}$	0.17*** [2.62] (0.014)
$\Delta \ln agri_{t-1}$	0.32 [0.44] (0.66)
$\Delta \ln ind_{t-1}$	0.19* [1.75] (0.09)
$\Delta \ln ser_{t-1}$	0.60** [2.03] (0.05)
No. of Obs.	32
R^2	0.75
DW Stat.	2.21

Note: We mention t-statistics in parenthesis [.] and p-value in brackets (.). ***, **, and * denote rejection of null hypothesis at 1, 5 and 10 % level of significance.

In the context of the above discussion it is also important to analyze how energy intensity is expected to change when structure of the economy changes in long run. We now turn our attention to this question by estimating equation (4). Table 5 presents the impact of the contribution of major sectors to GDP on the overall energy intensity. Table 5 shows that increases in shares of industry and services to GDP are expected to increase energy intensity and these effects are statistically significant at 10% and 5% levels of significance respectively. On the other hand, energy intensity is not expected to change significantly in response to changes in the GDP share of agriculture. Agriculture sector in Pakistan is less energy intensive as compare to industrial sector

5. Conclusions

The main objective of the study was to find the relationship between energy efficiency and economic growth. We used energy intensity as a proxy for energy efficiency. We used Vector Error Correction model to tests the existence of a long-term relationship between the energy intensity and GDP, while using this model to capture the Granger causality between variables. Using time series data Johansen co-integration test shows that long run relationship exists between energy intensity and GDP. Whereas results from VECM show that energy intensity is increasing with economic growth. Therefore, the increase in energy intensity is a result of economic growth in Pakistan that does not induce energy saving. As a result, energy consumption has grown more rapidly than GDP, which is supported by Huang et al. (2008). This study found that 1% increase in economic growth requires more than 1% increase in energy consumption in poor economies. The cost of converting energy into GDP is high in developing economies (Hannesson, 2002). The increase in energy intensity may also be the result of structural changes. In earlier phase of economic development, there is a shift away from agriculture towards heavy industry. This shift could increase the energy consumption because industrial sector is more energy intensive as compared to agriculture and services sectors.

The study finds that energy intensity is expected to increase if the shares of industry and services to GDP increase. These results have a number of implications. The industries are driver of economic growth in developing countries. Therefore, energy planning for industrial use has to be given utmost importance. In order to achieve the proposed objectives, energy intensities in industrial sector should be reduced through induction of energy efficient technologies in industrial sector. Transport sector is considered as a 60% of total services, it is highly energy intensive sector in Pakistan. Government should use energy efficient management policy for this sector. For example, government can promote public transport by introducing energy efficient transport system with the help of China in all major cities. This will help to reduce energy intensity. The role of CPEC is important because out of $57 billion under CPEC framework, the share of energy sector is around $35 billion. Again keeping in view the detailed layout of CPAC and the forecasted growths in various sectors of the economy, the economic planners of the country need to make future projections for the energy needs and used this important information for timely development of energy sector. There is a need to conduce a more detailed study to make projection for future energy requirements in order to be better informed for making credible plans for the energy sector.

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