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Article

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Investments in Energy Conservation: Policy Implications for Pakistan

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ABSTRACT

The paper investigates the impact of energy investment on economic growth for Pakistan using Solow (1956) model. The energy is introduced as factor input in the Solow (1956) growth model along with physical capital, labor and human capital and some other policy variables. The period of analysis ranges from 1970 to 2018. The Autoregressive Distributed Lag (ARDL) approach confirms that energy investment contributes positively to economic growth both in the short and the long run along with trade openness. The study provides an important policy recommendation that government should encourage the investment activities in energy sector to meet the rising energy demand which in turn stimulates economic growth.

Keywords: Energy Investments, Economic Growth, ARDL
JEL Classifications: O47, O13, Q43

1. INTRODUCTION

The continuous interest of economists in the analysis of determinants of growth, initiating in 19th century, has led to interesting modifications of growth models. This analysis has provided an insight into the diversified factors contributing to growth in the developing countries. Thus the horizon extended from traditional factors of production i.e. land, labor and capital to modern factors of production like infrastructure, energy and governance etc. Amongst other factors, the energy is found to be indispensable for sustained economic growth and development. The economists have recognized the position of energy in the production development and declared it as an essential factor of production (Cleveland et al., 1984; Murphy and Hall, 2010; Hall et al., 2000; Stern, 1997).

In the Keynesian framework, as consumption and income are significantly associated, similarly the energy consumption accelerates economic production. This increased output translates into economic growth and development in terms of higher per capita income through higher aggregate demand. The broad industrial development, suburbanization and growing population have increased the demand of energy, particularly in the emerging countries. Thus, it is widely believed that economic growth and energy usage are mutually dependent. However, the empirical investigation of the direction of relationship gives very interesting insights. There are several studies that believe that there is unidirectional causality from energy consumption to growth. These are Ramcharran (1990), Masih and Masih (1996), Morimoto and Hope (2004), Lee and Chang (2005), Altinay and Karagol (2005), Lee (2006), and Payne (2010). On the other hand, there are studies that found the relationship running from economic growth to energy consumption (Wolde-Rufael, 2006).

Investment is considered as key factor in generating the employment opportunities and encourages technological developments through embodiment of new skills. It helps to expand production frontier and increases the productivity. At the same time, investment spending is considered as unstable factor of aggregate demand because it depends on various economic and political factors. Any variation in investment creates two effects: the change in aggregate demand and a change in the productive capacity of the economy (Domar, 1946). The earlier studies on energy investment have mainly emphasized on energy protection investment and the long-run influences of research and development investment for renewed energy equipment. However, even within the prevailing energy structures, the augmented demand for energy in the primary and final energy mixes may require further investment in the energy. In addition, any effort to conserve energy through more effective technology, will add to the energy investment budget. Conservation investment leads to improve efficiency in energy usage through building insulation, energy efficient technologies and innovative production techniques. It is indirectly related with the energy sector and its special effects are not easily and clearly distinguishable, since it is spread out in the economy through capital regeneration investment.

In the developing countries, the transition to the market-based economy generates huge demand of energy, accompanied with a lot of bottlenecks in the supply of energy. "In such scenarios, the cost of energy investment can be much lower than the marginal cost of supply (Kushler et al., 2004). Therefore, not only could investment in energy efficiency defer supply investment in the future with much lower cost, but also bring tremendous economic and environmental benefits (Lin, 2007)."

Since at the micro level, the investment in energy is carried out by an industry or a firm, it is therefore important to analyze the firms' investment behavior. There can be a huge potential for energy conservation in the industries, but this can be dicey and may vary from sector to sector as all technologies may not be profitable for all sectors. The firms will invest in technologies that have positive net present value. There are several disturbing factors that can alter the cost of energy investment for the firm. These can be low expected energy prices, uncertainty due to expected fluctuations in energy prices, low expected revenues due to low energy bill, budgetary problems, too high required return on investment, reduction in production quality, bounded rationality, "technology-lock," information gap et*c*. There can be management barriers too in the form of no specialized personnel, no interest in energy conservation by management, no priority to conservation and lack of pressure.

Gillissen and Opschoor (1995) found that the decision to invest in energy is largely made on economic evaluation which keeps into account the financial and physical constraints. According to Sardianou (2008), an analysis of 779 Greek firms showed that there are organizational barriers to energy investment, as majority of the firms do not consider investment in energy as priority area. There are evidences of "demonstration effect" as majority of the firms decided to install energy saving technologies only if the other firms also install them.

In literature, energy investment is found to have both positive and negative effects on the economic progress. Ammad et al. (2013) empirically investigated the impact of public energy investment and found that it broadly speaking it positively effects the production of all sectors except the production of electricity and gas distribution. Smulders and Nooij (2003) found that the there is a possibility of an increase in per capita growth as the use of energy input declines because of "neoclassical scarcity effect." "This increased scarcity of energy inputs implies a higher marginal product of energy and makes a given growth rate of energy supply contribute more to growth (Smulders and Nooij, 2003)." In an extension of the Cobb Douglas production function, Suzuki and Takenaka (1981) found that Japan can achieve a higher growth rate with investment in energy conservation.

On the other hand, Samouilidis and Mitropoulos, (1983) theoretically showed energy investment leads to a reduction in the economic growth because investment in energy will require scanty funds from other productive sectors of economy. Smulders and Nooij (2003) developed a theoretical growth model and examined the impact of energy conservation on growth under different scenarios. Their robust analysis reveals that all energy conservation policies reduce per capita income. There is a possibility that a win-win situation might not arise, as any reduction in energy input, may be offset by the increase in expenditure on research and development. The analysis of the energy-trade-growth nexus by Raza et al. (2015) in case of Pakistan revealed that use of energy conservation policies reduce trade performance, leading to decline in economic growth.

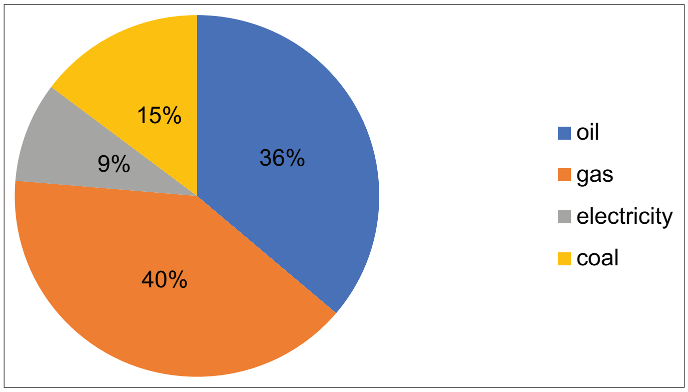
The natural question that arises is: "What is the impact of energy investment on economic development?" and its answer is imperative to policymakers. The rest of the article is organized as follows. Section 2 provides an overview of Pakistan's energy sector. The methodology and data are discussed in section 3, section 4 describes the empirical findings in detail, and section 5 concludes the study.

2. AN OVER VIEW OF ENERGY SECTOR IN PAKISTAN

Energy crises have been adversely affecting Pakistan since 2007 and became most serious issue in 2012. It negatively affects the economic performance. Net primary energy supply was 86301 thousand TOEs (tonnes of oil equivalent) in 2017-18 which was 64588 thousand TOEs in 2012-2013. The average growth rate of net energy supply was 6%. The total energy consumption in 2017-2018 was 54992 thousand TOEs. The average growth rate of energy consumption in Pakistan was 9.7% in 2017-2018 as compared to 2016-2017 due to major increase in industrial, transport and agriculture sector. The sectoral share of energy supply shows that gas and oil have largest share in energy supply of Pakistan. Gas contributes 34.6%, Oil contributes 31.2%, electricity contributes 7.7% and coal contributes approximately 12.7% in total energy supply of Pakistan in 2017-2018. Figure 1 shows the sectoral share of energy supply of Pakistan.

On the demand side, the growth rate of demand of electricity was 4% per annum in 1990s which has increased to 7% per year annum

Figure 1: Sectoral share of energy supply of Pakistan



during the period of 1999-2000 to 2006-2007. Electricity demand has been growing 3 to 4% per year up to 2003-2004. However, it increased rapidly in succeeding years and reached up to 10% during the period of 2007-2008. This huge increase in electricity demand happened due to increase in population and expansion in the economy. In 2017-2018 it grew by 15.8%.

During the last 5 years the economy of Pakistan has grown on average at the rate of 2.9% per annum. Energy demand is increasing rapidly due to rise in population and economic development while energy supply could not be increased due to deterioration in the power sector. This resulted in power outages to tackle the shortfall. The constraints on fuel supply and poor situation of hydroelectric production furthered the shortfall. This excess energy demand highlights the need to invest in energy sector to meet the economic needs of energy and it might allow the country to get higher growth level and employment opportunities.

- Total gross fixed capital formation in electricity generation and distribution and gas distribution increased to 243001 million rupees in 2017-2018 which was 147714 million rupees in 2016-17 in both public, private and general government sector.
- The gross fixed capital formation in electricity generation and distribution and gas distribution in private sector has been reduced to 6327 million rupees in 2017-2018 which was 9193 million rupees in 2016-2017.
- In public and general government sectors, it has been increased to 236674 million rupees in 2017-2018 which was 138521 million rupees in 2016-2017.

3. METHODOLOGICAL FRAMEWORK AND DESCRIPTION OF VARIABLES

To find the relationship between economic growth and investment in energy we include the energy as a factor input in MRW growth model:

$$Y(t) = (A(t), K(t), L(t), H(t), E(t)) = K(t)^{\alpha}\ H(t)^{\beta}\ E(t)^{\gamma}(A(t)L(t))^{1-\alpha-\beta-\gamma} \tag{3.1}$$

Dividing Equation (3.2) by $A(t)\,L(t)$

$$\frac{Y(t)}{A(t)L(t)} = \frac{K(t)^{\alpha}\ H(t)^{\beta}\ E(t)^{\gamma}(A(t)L(t))^{1-\alpha-\beta-\gamma}}{A(t)L(t)}$$

$$= \frac{K(t)^{\alpha}\ H(t)^{\beta}\ E(t)^{\gamma}}{(A(t)L(t))^{\alpha+\beta+\gamma}}$$

$$\frac{Y(t)}{A(t)L(t)} = \frac{K(t)^{\alpha}\ H(t)^{\beta}\ E(t)^{\gamma}}{(A(t)L(t))^{\alpha}(A(t)L(t))^{\beta}(A(t)L(t))^{\gamma}}$$

$$= \left(\frac{K(t)}{A(t)L(t)}\right)^{\alpha}\left(\frac{H(t)}{A(t)L(t)}\right)^{\beta}\left(\frac{E(t)}{A(t)L(t)}\right)^{\gamma}$$

Now we take

$$k(t) = \frac{K(t)}{A(t)L(t)}$$

Taking the derivative of the above equation with respect to time

$$\frac{dk(t)}{dt} = \frac{\dot{K}(t)}{A(t)L(t)} - \frac{K(t)}{(A(t)L(t))^2}\left(\dot{A}(t)\,L(t) + A(t)\,\dot{L}(t)\right)$$

Using equation (4) in equation (3) yield

$$\frac{dk(t)}{dt} = \frac{s_k Y(t) - \delta\, K(t)}{A(t)L(t)} - \frac{K(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{dk(t)}{dt} = \frac{s_k Y(t)}{A(t)L(t)} - \frac{\delta\, K(t)}{A(t)L(t)} - \frac{K(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{dk(t)}{dt} = s_k y(t) - \delta\, k(t) - k(t)\left(g+n\right)$$
$$= s_k y(t) - \left(n+g+\delta\right)k(t) \tag{3.6}$$

$$y(t) = \frac{Y(t)}{A(t)L(t)}, \qquad k(t) = \frac{K(t)}{A(t)L(t)}, \quad n = \frac{\dot{L}(t)}{L(t)}, \quad g = \frac{\dot{A}(t)}{A(t)}$$

Where

$$\frac{dk(t)}{dt} = s_k y(t) - \left(n+g+\delta\right)k(t) \tag{3.7}$$

Steady state (equilibrium) occur at the point where $\frac{dk(t)}{dt} = 0$

Now equation (3.7) becomes as

$$s_k y(t) = \left(n+g+\delta\right)k(t)$$

$$s_k\ k(t)^{\alpha}\ h(t)^{\beta}\ e(t)^{\gamma} = \left(n+g+\delta\right)k(t)$$

$$\frac{s_k}{n+g+\delta} = \frac{k(t)}{k(t)^{\alpha}\ h(t)^{\beta}\ e(t)^{\gamma}} = \frac{k(t)^{1-\alpha}}{h(t)^{\beta}\ e(t)^{\gamma}}$$

$$k(t)^{1-\alpha} = \frac{s_k\, h(t)^{\beta}\, e(t)^{\gamma}}{n+g+\delta}$$

$$k(t) = \left(\frac{s_k\, h(t)^{\beta}\, e(t)^{\gamma}}{n+g+\delta}\right)^{1/1-\alpha} \quad (3.8)$$

Now we take

$$h(t) = \frac{H(t)}{A(t)L(t)}$$

Taking the derivative of the above equation with respect to time

$$\frac{dh(t)}{dt} = \frac{\dot{H}(t)}{A(t)L(t)} - \frac{H(t)}{(A(t)L(t))^2}\left(\dot{A}(t)\,L(t) + A(t)\,\dot{L}(t)\right) \quad (3.9)$$

If we denote investment in human capital by S_h then net investment in human capital will be

$$\dot{H}(t) = \frac{dH(t)}{dt} = s_h Y(t) - \delta\, H(t) \quad (3.10)$$

Using equation (3.10) in equation (3.9) we get

$$\frac{dh(t)}{dt} = \frac{s_h Y(t) - \delta\, H(t)}{A(t)L(t)} - \frac{H(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{dh(t)}{dt} = \frac{s_h Y(t)}{A(t)L(t)} - \frac{\delta\, H(t)}{A(t)L(t)} - \frac{H(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{dh(t)}{dt} = s_h y(t) - \delta\, h(t) - h(t)\left(g+n\right) = s_h y(t) - \left(n+g+\delta\right)h(t) \quad (3.11)$$

$$\frac{dh(t)}{dt} = s_h y(t) - \left(n+g+\delta\right)h(t) \quad (3.12)$$

Steady state (Equilibrium) occur at the point where $\frac{dh(t)}{dt} = 0$

Now equation (3.12) becomes as

$$s_h y(t) = \left(n+g+\delta\right)h(t)$$

$$s_h\, k(t)^{\alpha}\, h(t)^{\beta}\, e(t)^{\gamma} = \left(n+g+\delta\right)h(t)$$

$$\frac{s_h}{n+g+\delta} = \frac{h(t)}{k(t)^{\alpha}\, h(t)^{\beta}\, e(t)^{\gamma}} = \frac{h(t)^{1-\beta}}{k(t)^{\alpha}\, e(t)^{\gamma}}$$

$$h(t)^{1-\beta} = \frac{s_h\, k(t)^{\alpha}\, e(t)^{\gamma}}{n+g+\delta}$$

$$h(t) = \left(\frac{s_h\, k(t)^{\alpha}\, e(t)^{\gamma}}{n+g+\delta}\right)^{1/1-\beta} \quad (3.13)$$

Now we take

$$e(t) = \frac{E(t)}{A(t)L(t)}$$

Taking the derivative of the above equation with respect to time

$$\frac{de(t)}{dt} = \frac{\dot{E}(t)}{A(t)L(t)} - \frac{E(t)}{(A(t)L(t))^2}\left(\dot{A}(t)\,L(t) + A(t)\,\dot{L}(t)\right) \quad (3.14)$$

If we denote investment in energy sector by S_e then net invest in energy sector will be

$$\dot{E}(t) = \frac{dE(t)}{dt} = s_e Y(t) - \delta\, E(t) \quad (3.15)$$

Using equation (3.15) in equation (3.14) we get

$$\frac{de(t)}{dt} = \frac{s_e Y(t) - \delta\, E(t)}{A(t)L(t)} - \frac{E(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{de(t)}{dt} = \frac{s_e Y(t)}{A(t)L(t)} - \frac{\delta\, E(t)}{A(t)L(t)} - \frac{E(t)}{(A(t)L(t))}\left(\frac{\dot{A}(t)}{A(t)} + \frac{\dot{L}(t)}{L(t)}\right)$$

$$\frac{de(t)}{dt} = s_e y(t) - \delta\, e(t) - e(t)\left(g+n\right) = s_e y(t) - \left(n+g+\delta\right)e(t) \quad (3.16)$$

$$\frac{de(t)}{dt} = s_e y(t) - \left(n+g+\delta\right)e(t) \quad (3.17)$$

Steady state (equilibrium) occur at the point where $\frac{de(t)}{dt} = 0$

Now equation (3.17) becomes as

$$s_e y(t) = \left(n+g+\delta\right)e(t) \Rightarrow$$

$$s_e\, k(t)^{\alpha}\, h(t)^{\beta}\, e(t)^{\gamma} = \left(n+g+\delta\right)e(t)$$

$$\frac{s_e}{n+g+\delta} = \frac{e(t)}{k(t)^{\alpha}\, h(t)^{\beta}\, e(t)^{\gamma}} = \frac{e(t)^{1-\gamma}}{k(t)^{\alpha}\, h(t)^{\beta}}$$

$$e(t)^{1-\gamma} = \frac{s_e\, k(t)^{\alpha}\, h(t)^{\beta}}{n+g+\delta}$$

$$e(t) = \left(\frac{s_e\, k(t)^{\alpha}\, h(t)^{\beta}}{n+g+\delta}\right)^{1/1-\gamma} \quad (3.18)$$

Now we solve equation (3.8), (3.13) and (3.18) simultaneously

Using equation (3.8) in (3.13), we get

$$h(t) = \left(\frac{s_h \left(\frac{s_k\, h(t)^{\beta}\, e(t)^{\gamma}}{n+g+\delta} \right)^{\alpha/1-\alpha} e(t)^{\gamma}}{n+g+\delta} \right)^{1/1-\beta}$$

$$h(t) = \left(\frac{s_h\, s_k^{\alpha/1-\alpha}\, h(t)^{\alpha\beta/1-\alpha}\, e(t)^{\alpha\gamma/1-\alpha}\, e(t)^{\gamma}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\beta}$$

$$h(t) = \left(\frac{s_h\, s_k^{\alpha/1-\alpha}\, e(t)^{\alpha\gamma/1-\alpha}\, e(t)^{\gamma}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\beta} h(t)^{\alpha\beta/(1-\alpha)(1-\beta)}$$

$$\frac{h(t)}{h(t)^{\alpha\beta/(1-\alpha)(1-\beta)}} = \left(\frac{s_h\, s_k^{\alpha/1-\alpha}\, e(t)^{\alpha\gamma/1-\alpha}\, e(t)^{\gamma}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\beta}$$

$$h(t)^{1-\alpha-\beta/(1-\alpha)(1-\beta)} = \left(\frac{s_h\, s_k^{\alpha/1-\alpha}\, e(t)^{\alpha\gamma/1-\alpha}\, e(t)^{\gamma}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\beta}$$

$$h(t) = \left(\frac{s_h\, s_k^{\alpha/1-\alpha}\, e(t)^{\alpha\gamma/1-\alpha}\, e(t)^{\gamma}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1-\alpha/1-\alpha-\beta}$$

$$h(t) = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, e(t)^{\gamma}}{n+g+\delta} \right)^{1/1-\alpha-\beta} \qquad (3.19)$$

Using equation (3.8) in (3.18)

$$e(t) = \left(\frac{s_e \left(\frac{s_k\, h(t)^{\beta}\, e(t)^{\gamma}}{n+g+\delta} \right)^{\alpha/1-\alpha} h(t)^{\beta}}{n+g+\delta} \right)^{1/1-\gamma}$$

$$e(t) = \left(\frac{s_e\, s_k^{\alpha/1-\alpha}\, h(t)^{\beta/1-\alpha}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\gamma} e(t)^{\alpha\gamma/(1-\alpha)(1-\gamma)}$$

$$\frac{e(t)}{e(t)^{\alpha\gamma/(1-\alpha)(1-\gamma)}} = \left(\frac{s_e\, s_k^{\alpha/1-\alpha}\, h(t)^{\beta/1-\alpha}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\gamma}$$

$$e(t)^{1-\alpha-\gamma/(1-\alpha)(1-\gamma)} = \left(\frac{s_e\, s_k^{\alpha/1-\alpha}\, h(t)^{\beta/1-\alpha}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1/1-\gamma}$$

$$e(t) = \left(\frac{s_e\, s_k^{\alpha/1-\alpha}\, h(t)^{\beta/1-\alpha}}{(n+g+\delta)^{1/1-\alpha}} \right)^{1-\alpha/1-\alpha-\gamma}$$

$$e(t) = \left(\frac{s_e^{1-\alpha}\, s_k^{\alpha}\, h(t)^{\beta}}{n+g+\delta} \right)^{1/1-\alpha-\gamma} \qquad (3.20)$$

Using equation (3.20) in equation (3.19)

$$h(t) = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha} \left(\frac{s_e^{1-\alpha}\, s_k^{\alpha}\, h(t)^{\beta}}{n+g+\delta} \right)^{\gamma/1-\alpha-\gamma}}{n+g+\delta} \right)^{1/1-\alpha-\beta}$$

$$h(t) = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, s_e^{(1-\alpha)\gamma/1-\alpha-\gamma}\, s_k^{\alpha\gamma/1-\alpha-\gamma}}{(n+g+\delta)^{\frac{1-\alpha}{1-\alpha-\gamma}}} \right)^{1/1-\alpha-\beta} h(t)^{\beta\gamma/(1-\alpha-\gamma)(1-\alpha-\beta)}$$

$$\frac{h(t)}{h(t)^{\beta\gamma/(1-\alpha-\gamma)(1-\alpha-\beta)}} = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, s_e^{(1-\alpha)\gamma/1-\alpha-\gamma}\, s_k^{\alpha\gamma/1-\alpha-\gamma}}{(n+g+\delta)^{\frac{1-\alpha}{1-\alpha-\gamma}}} \right)^{1/1-\alpha-\beta}$$

$$h(t)^{\frac{(1-\alpha)(1-\alpha-\beta-\gamma)}{(1-\alpha-\gamma)(1-\alpha-\beta)}} = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, s_e^{(1-\alpha)\gamma/1-\alpha-\gamma}\, s_k^{\alpha\gamma/1-\alpha-\gamma}}{(n+g+\delta)^{\frac{1-\alpha}{1-\alpha-\gamma}}} \right)^{1/1-\alpha-\beta}$$

$$h(t) = \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, s_e^{(1-\alpha)\gamma/1-\alpha-\gamma}\, s_k^{\alpha\gamma/1-\alpha-\gamma}}{(n+g+\delta)^{\frac{1-\alpha}{1-\alpha-\gamma}}} \right)^{\frac{(1-\alpha-\gamma)}{(1-\alpha)(1-\alpha-\beta-\gamma)}}$$

$$h(t) = \left(\frac{s_h^{1-\alpha-\gamma}\, s_k^{\alpha}\, s_e^{\gamma}}{n+g+\delta} \right)^{1/1-\alpha-\beta-\gamma} \qquad (3.21)$$

Using equation (3.19) in equation (3.20)

$$e(t) = \left(\frac{s_e^{1-\alpha}\, s_k^{\alpha} \left(\frac{s_h^{1-\alpha}\, s_k^{\alpha}\, e(t)^{\gamma}}{n+g+\delta} \right)^{\beta/1-\alpha-\beta}}{n+g+\delta} \right)^{1/1-\alpha-\gamma}$$

$$e(t) = \left(\frac{s_e^{1-\alpha}\, s_k^{\alpha}\, s_h^{(1-\alpha)\beta/1-\alpha-\beta}\, s_k^{\alpha\beta/1-\alpha-\beta}\, e(t)^{\gamma\beta/1-\alpha-\beta}}{(n+g+\delta)^{1-\alpha/1-\alpha-\beta}} \right)^{1/1-\alpha-\gamma}$$

$$e(t)=\left(\frac{s_e^{1-\alpha}\ s_k^{\alpha}\ s_h^{(1-\alpha)\beta/1-\alpha-\beta}\ s_k^{\alpha\beta/1-\alpha-\beta}}{(n+g+\delta)^{1-\alpha/1-\alpha-\beta}}\right)^{1/1-\alpha-\gamma}$$
$$e(t)^{\beta\gamma/(1-\alpha-\beta)(1-\alpha-\gamma)}$$

$$\frac{e(t)}{e(t)^{\beta\gamma/(1-\alpha-\beta)(1-\alpha-\gamma)}}=\left(\frac{s_e^{1-\alpha}\ s_k^{\alpha}\ s_h^{(1-\alpha)\beta/1-\alpha-\beta}\ s_k^{\alpha\beta/1-\alpha-\beta}}{(n+g+\delta)^{1-\alpha/1-\alpha-\beta}}\right)^{1/1-\alpha-\gamma}$$

$$e(t)^{\frac{(1-\alpha)(1-\alpha-\beta-\gamma)}{(1-\alpha-\beta)(1-\alpha-\gamma)}}=\left(\frac{s_e^{1-\alpha}\ s_k^{\alpha}\ s_h^{(1-\alpha)\beta/1-\alpha-\beta}\ s_k^{\alpha\beta/1-\alpha-\beta}}{(n+g+\delta)^{1-\alpha/1-\alpha-\beta}}\right)^{1/1-\alpha-\gamma}$$

$$e(t)=\left(\frac{s_e^{1-\alpha}\ s_k^{\alpha}\ s_h^{(1-\alpha)\beta/1-\alpha-\beta}\ s_k^{\alpha\beta/1-\alpha-\beta}}{(n+g+\delta)^{1-\alpha/1-\alpha-\beta}}\right)^{\frac{1-\alpha-\beta}{(1-\alpha)(1-\alpha-\beta-\gamma)}}$$

$$e(t)=\left(\frac{s_e^{1-\alpha-\beta}\ s_k^{\alpha}\ s_h^{\beta}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \quad (3.22)$$

Using equation (3.21) and (3.22) in equation (3.8)

$$k(t)=\left(\frac{s_k\left(\frac{s_h^{1-\alpha-\gamma}\ s_k^{\alpha}\ s_e^{\gamma}}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta-\gamma}} z\left(\frac{s_e^{1-\alpha-\beta}\ s_k^{\alpha}\ s_h^{\beta}}{n+g+\delta}\right)^{\frac{\gamma}{1-\alpha-\beta-\gamma}}}{n+g+\delta}\right)^{1/1-\alpha}$$

$$k(t)=\left(\frac{s_k\left(\frac{s_h^{1-\alpha-\gamma}\ s_k^{\alpha}\ s_e^{\gamma}}{n+g+\delta}\right)^{\frac{\beta}{1-\alpha-\beta-\gamma}}\left(\frac{s_e^{1-\alpha-\beta}\ s_k^{\alpha}\ s_h^{\beta}}{n+g+\delta}\right)^{\frac{\gamma}{1-\alpha-\beta-\gamma}}}{n+g+\delta}\right)^{1/1-\alpha}$$

$$k(t)=\left(\frac{s_h^{\beta(1-\alpha-\gamma)/1-\alpha-\beta-\gamma}\ s_k^{\alpha\beta/1-\alpha-\beta-\gamma}\ s_e^{\beta\gamma/1-\alpha-\beta-\gamma}\ s_e^{\gamma(1-\alpha-\beta)/1-\alpha-\beta-\gamma}\ s_k^{\alpha\gamma/1-\alpha-\beta-\gamma}\ s_h^{\beta\gamma/1-\alpha-\beta-\lambda}}{(n+g+\delta)^{1/1-\alpha}}\right)^{1/1-\alpha}$$

After simplification

$$k(t)=\left(\frac{s_k^{1-\beta-\gamma}\ s_h^{\beta}\ s_e^{\gamma}}{n+g+\delta}\right)^{\frac{1}{1-\alpha-\beta-\gamma}} \quad (3.23)$$

Using equation (3.23), (3.22) and (3.21) in equation (3.3)

$$y(t)=\left(\frac{s_k^{1-\beta-\gamma}\ s_h^{\beta}\ s_e^{\gamma}}{n+g+\delta}\right)^{\alpha/1-\alpha-\beta-\gamma}\left(\frac{s_h^{1-\alpha-\gamma}\ s_k^{\alpha}\ s_e^{\gamma}}{n+g+\delta}\right)^{\beta/1-\alpha-\beta-\gamma}\left(\frac{s_e^{1-\alpha-\beta}\ s_k^{\alpha}\ s_h^{\beta}}{n+g+\delta}\right)^{\gamma/1-\alpha-\beta-\gamma}$$

Simplifying the above equation, we get

$$y(t)=\left(s_k^{\alpha}\ s_h^{\beta}\ s_e^{\gamma}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}(n+g+\delta)^{-\left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right)}$$

$$\frac{Y(t)}{A(t)L(t)}=\left(s_k^{\alpha}\ s_h^{\beta}\ s_e^{\gamma}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}(n+g+\delta)^{-\left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right)}$$

$$\frac{Y(t)}{L(t)}=A(t)\left(s_k^{\alpha}\ s_h^{\beta}\ s_e^{\gamma}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}(n+g+\delta)^{-\left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right)}$$

$$\frac{Y(t)}{L(t)}=A(t)\left(s_k^{\alpha}\ s_h^{\beta}\ s_e^{\gamma}\right)^{\frac{1}{1-\alpha-\beta-\gamma}}(n+g+\delta)^{-\left(\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\right)}$$

Taking "ln" on both sides of the above equation we get

$$\ln\left(\frac{Y(t)}{L(t)}\right)=\ln A(t)+\frac{\alpha}{1-\alpha-\beta-\gamma}\ln s_k+\frac{\beta}{1-\alpha-\beta-\gamma}\ln s_h+\frac{\gamma}{1-\alpha-\beta-\gamma}\ln s_e-\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}\ln(n+g+\delta) \quad (3.24)$$

$$\ln\left(\frac{Y(t)}{L(t)}\right)=\beta_0+\beta_1\ln s_k+\beta_2\ln s_h+\beta_3\ln s_e+\beta_4\ln(n+g+\delta) \quad (3.25)$$

Where

$$\beta_0=\ln A(t),\ \beta_1=\frac{\alpha}{1-\alpha-\beta-\gamma},\ \beta_2=\frac{\beta}{1-\alpha-\beta-\gamma},$$
$$\beta_3=\frac{\gamma}{1-\alpha-\beta-\gamma},\ \beta_4=-\frac{\alpha+\beta+\gamma}{1-\alpha-\beta-\gamma}$$

As per the literature on economic growth various control variables such as inflation (INF), trade openness (TOP), foreign direct investment (FDI) and external debt (ED) have been included in the growth regression. Equation (3.25) is further generalized by incorporating these variables. The model is thus specified as:

$$\ln\left(\frac{Y(t)}{L(t)}\right)=\beta_0+\beta_1\ln s_k+\beta_2\ln s_h+\beta_3\ln s_e+\beta_4\ln(n+g+\delta)+\beta_5\ln INF+\beta_6\ln FDI+\beta_7\ln TOP+\beta_8\ln ED \quad (3.26)$$

The eq. 3.26 is estimated through cointegration. There are several techniques to estimate cointegration. This study prefers auto regressive distributed lag model (ARDL) posited by Pesaran and Shin (1999) and furthered by Pesaran et al. (2001) due to its various advantages. "This technique can be applied in case the variables are I (0), I (1) or mix of both. However, the fundamental assumptions of the ARDL approach are violated if the integration order of any variable is larger than one (Ouattara, 2004). Using ARDL, the long and short run impacts of variables could be found out at the same time. This technique gives super consistent results in case of small samples and deals with endogeneity. The other advantage of this technique is that it linearizes transformation for error correction model (ECM) (Jalil et al., 2016)."

The ARDL technique proceeds with following steps. In the first step we check for the presence of long run relationship and in the second step we compute short run coefficients via ECM. The bound testing approach of ARDL gives the values of the parameters by OLS (ordinary least square) method. The null hypothesis is represented by

$$H_0 : \theta_Y = \theta_k = \theta_h = \theta_e = \theta_{n+g+\delta}$$
$$= \theta_{\text{INF}} = \theta_{\text{TOP}} = \theta_{FDI} = \theta_{ED} = 0 \ ,$$

The critical values of the testing of joint significance have been provided by Pesaran et al. (2001) The presence of long run relationship is determined on the basis of the Lower critical bound (LCB) and the upper critical bound (UCB). The result is declared inconclusive if the calculated value of the F-test falls between the two bounds.

This is followed by other standard diagnostics tests which includes the Jarque-Bera (JB) test for normality, the Breusch Godfrey LM test for autocorrelation and the ARCH test for heteroskedasticity. Finally, the structural stability of the parameters is tested using the CUSUM and CUSUMSQ test (cumulative sum of squares of residuals).

3.1. Data and Variable Construction

The analysis requires data on economic growth, inflation (INF), trade openness (TOP), foreign direct investment (FDI) and external debt (ED), share of investment in physical capital (S_k), share of investment in human capital (S_h), share of investment in energy (S_e) and annual growth rate of labor force, depreciation rate and growth rate of technology.

We have used gross domestic product per capita measured in constant local currency as proxy of economic growth. The data on this variable is taken from World Development Indicator. We used the ratio of physical capital stock to GDP as a share of investment in physical capital (S_k). The gross fixed capital formation in current market prices is used as a proxy of physical capital stock. We divided the series by gross domestic product at constant factor cost of 1999-2000 and obtained the investment in physical capital (ratio of GDP).

As the investment in electricity generation, distribution and gas distribution is included in gross fixed capital formation so we have used gross fixed capital formation after subtracting the investment in electricity generation, distribution and gas distribution from gross fixed capital formation. The data on this variable is taken from several issues of Pakistan economic survey. Annual growth rate of labor force is used as growth rate of labor force (n). The data on labor force is taken from various issues of Pakistan economic survey. Technology growth rate g plus depreciation rate δ is assumed to be 0.05 (Mankiw et al., 1992). We have used human capital to labor force ratio as a share of investment in human capital (S_h). This proxy is also used by Mankiw et al. (1992). The total enrolment in secondary education is used as a proxy for Human capital (H) following Risikat (2010), Abbas (2000), and Khan (2012). The data on enrolment in secondary education is taken from various issues of Pakistan economic survey. The gross fixed capital formation in electricity generation, distribution and gas distribution in current market prices is used as investment in energy. Our study will use the ratio of investment in energy to GDP as a share of investment in energy (S_e). The annual time series data for this variable is taken from various issues of Pakistan economic surveys.

The consumer price index (CPI) annual percent is used as a proxy for inflation. This proxy is also used by Ali et al. (2012), Najia et al. (2013). The data on this variable is taken from World Development Indicator. A ratio of imports plus exports to GDP is used as a proxy of trade openness. This proxy is also used by Shahbaz et al. (2008), Ul Husnain et al. (2011) and Balamurali et al. (2004). The data on this variable is derived from various issues of Pakistan economic survey. The external debt stock percentage of gross national income is used as a proxy of external debt (ED). The data on this variable is derived from WDI.

4. EMPIRICAL RESULTS

The results of ADF unit root test for all the variables are reported in appendix. The gross domestic product per capita (Y/L), share of investment in human capital (S_h), share of investment in energy (S_e), inflation rate (INF) and foreign direct investment are integrated of order one, while growth rate of labor force plus depreciation rate plus growth rate of technology ($n+g+\delta$), trade openness (TOP), share of investment in physical capital (S_k) and external debt (ED) are integrated of order zero. The application of ARDL co-integration technique of Pesaran et al. (2001) is further supported by the order of integration of the variables.

The literature suggests different criteria like log likelihood (LL), likelihood ratio (LR), final prediction error (FPE), Akaike information criterion (AIC), Schwarz Bayesian Criterion (SBC) and Hannan Quinn Information Criterion (HQ) to choose optimal lags of VAR model. In our study Akaike Information Criterion (AIC) is followed. Table 1 reports the results for optimal lag length. AIC exhibits smallest value corresponding to lag 2.

The calculated value of F-statistic is 6.068. The calculated value exceeds the upper critical bound at 95% (Table 2). Thus a long run relationship exists between economic growth (Y/L) and share of energy investment (S_e), along other control variables. The estimated results of the long run association among economic

Table 1: Appropriate lag length selection results

Lag	LogL	LR	FPE	AIC	SC	HQ
0	2.690059	NA	1.10e-11	0.307802	0.683952	0.444775
1	280.2665	419.7498	8.24e-16	−9.281294	−5.519794*	−7.911563
2	399.8826	128.3685*	2.28e-16*	−11.16500*	−4.018155	−8.562516*

*Indicates lag order selected by the criterion. The F statistics is reported in the Table 2

Table 2: Bound test results

F-statistics	I (0)	I (1)	Cointegration
	$F_{\ln y}(\ln y/\ln s_k, \ln s_h, \ln s_e, \ln INF, \ln TOP, \ln FDI, \ln ED, \ln(n+\delta+g))$		
6.068	2.27	3.28	Yes

Critical values are given only at 5% significance level

Table 3: Long results of growth model with energy and other control variables

Variable	Coefficient	SE	t-statistic
C	3.477	0.656	5.304***
$\ln(n+g+\delta)$	−0.026	0.018	−1.440
ln*INF*	−0.049	0.011	−4.529***
$\ln S_e$	0.035	0.013	2.694***
$\ln S_h$	0.049	0.023	2.121***
$\ln S_k$	0.056	0.016	3.561***
ln*TOP*	0.318	0.098	3.258***
ln*FDI*	−0.008	0.004	−1.853*
ln*ED*	−0.134	0.038	−3.585***

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

growth and share of energy investment with other control variables are given in Table 3.

The estimated coefficient of energy investment has a positive sign and highly significant impact on economic growth. The energy investment thereby contributes positively to output (Ammad and Ahmed, 2013). In literature, our results are supported by Ammad and Ahmed (2013).

The estimated coefficients of the long run relationship show that trade openness (ratio of exports plus imports to GDP) has an expected negative sign and does not significantly affect the GDP per capita proxied by economic growth. "The potential growth effects of trade liberalization are well known. While the intermediate impact is likely to be negative, as resources become redundant in areas of comparative disadvantage, their eventual reallocation into areas of comparative advantage will increase the growth rate; the evidence points to a J curve-type response (Greenaway et al., 2002; Falvey et al., 2012)."

The rate of inflation (INF) has negative effect on economic growth with higher level of significant. The estimated coefficient shows that higher inflation reduces economic growth. In literature our results are consistent with Kowalski (2000), Najia et al. (2013) and Ali et al. (2012).

The estimated coefficients of the long run relationship show that trade openness (ratio of exports plus imports to GDP) has an expected positive sign and highly significant impact on GDP per capita proxied by economic growth. Thus, more openness leads to higher economic growth as the specialization possible through trade increases the productivity of the workers. As a result, the output of the economy will rise. The trade openness also increases markets for new products and leads to generate the benefits arising from competition and economies of scale. Our results are confirmed by the study of Qadir (2000).

The coefficient of external debt, it found to be negative and has highly significant impact on economic growth. The possible reason of negative sign of external debt might be that most of the resources are transferred in the debt payments rather than on investment purposes. As a result, lesser amount of funds will be used for services such as schools, construction of new roads, new business opportunities and hospitals. Another possible reason might be that more external debt payments force the government to increase taxes to finance the high debt payments. That increase in taxes leads to increase interest rate which in turn discouraged the investment projects. The reduction in investment leads to reduce economic growth. Therefore, external debt is negatively associated to economic growth. In literature our results are confirmed by the study of Najia et al. (2013).

The estimated coefficients of the long run relationship show that human capital has negative sign but statistically insignificant indicating no significant impact of human capital on economic growth. The reason might be that the high drop-out ratios because of which all students that get admission in school do not complete their education, as a result, human capital may not be found significant and also have negative effect on economic growth (Nelson et al., 1966). Our results are consistent with Dulleck and Foster (2008).

The estimated coefficient of FDI is contributing negatively and significantly to economic growth only at 10% level of significance. The possible reason of the negative sign of FDI may be the energy crises, underdeveloped infrastructure and unskilled labor force. The results are consistent with Najia et al. (2013) and Usman (2012).

"The high significance coefficient of ECM_{t-1} term confirms the presence of cointegration between the variables (Banerjee et al., 1998)." The estimated results of short run dynamics are reported in Table 4. These results are obtained from the error correction (ECM) approach. The high significance ECM term in our analysis confirms the existence of cointegration relationship between

Table 4: Short run results of growth model with energy and other control variables

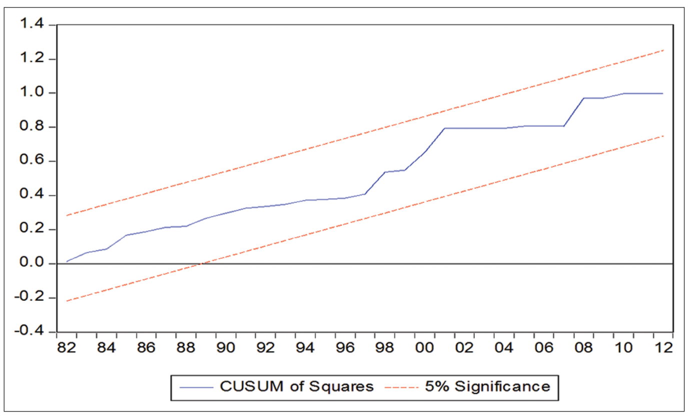
Variable	Coefficient	SE	t-statistic	Prob.
C	3.4772	0.4030	8.6275	0.0000
Δ(ln (Y/L(−1))	−0.6027	0.0.1205	−5.0018*	0.0000
Δ(ln (TOP)	0.1347	0.0363	3.7080*	0.0008
Δ(ln (TOP(−1))	−0.2353	0.0422	−5.5733*	0.0000
Δ(ln (INF(−1))	0.0449	0.0079	5.67*	0.0000
Δ(ln (ED)	−0.2197	0.0307	−7.1656*	0.0000
Δ(ln (ED(−1))	0.0268	0.0051	5.2797*	0.0000
Δ(ln (ED(−2))	0.0132	0.0038	3.4686*	0.0016
ECM(−1)	−0.2110	0.0246	−8.5798*	0.0000
R-squared	0.7534	F-statistic	11.8362	
Adjusted R-squared	0.6897	Prob.(F-statistic)	0.0000	

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

Table 5: Diagnostic tests on growth model with energy and other control variables

Test	Test Statistic	Prob.	Critical value
Normality test	2.8311	0.2428	$\chi^2_{0.05(2)} = 5.99$
Serial correlation LM test	0.6291	0.4277	$\chi^2_{0.05(1)} = 3.84$
ARCH test	0.2421	0.6227	$\chi^2_{0.05(1)} = 3.84$
Ramsey reset test	0.0180	0.8939	$\chi^2_{0.05(1)} = 3.84$

Figure 2: Cumulative sum of square residuals of growth model with energy and other control variables (CUSUMSQ)



economic growth (Y/L) and share of energy investment (S_e) with other control variables. The speed of adjustment coefficient is found to be -0.2110 which is highly significant at 5% level of significance (Table 4). It shows that previous period discrepancy in equilibrium is corrected with an adjustment speed of 21.10% per year.

To determine the robustness of the analysis, the diagnostic tests such as normality, serial correlation, heteroskedasticity and Ramsey test and stability tests are also carried out which are reported in Table 5. Whereas, stability tests are shown in Figure 2.

5. CONCLUSION AND POLICY RECOMMENDATIONS

In literature, there is a plethora of studies extensively analyzing the impact of energy consumption on economic growth both for developed and developing countries, as mentioned in our study. However, there is scarce evidence of how the investment in energy effects economic growth. There is not even a single study in case of Pakistan. The present study attempts to initiate the debate on this area of research by incorporating energy as factor input in the growth model (Mankiw et al., 1992) along with physical capital, labor and human capital. An autoregressive distributed lag (ARDL) approach is applied to study the long run association between economic growth and energy investment for the period of 1970-2012. The short run dynamics of Pakistan's economic growth are examined through error correction mechanism (ECM).

The most important result of this study is that energy investment has a positive significant effect on economic growth in the long run. More technically, this result reveals that energy investment boosts economic growth in the long run in case of Pakistan. These findings are in line with the Keynesian school of thought which is of the view that increase in investment induces aggregate demand which in turn accelerates economic growth. The other variables like Inflation, trade openness, external debt and foreign direct investment are in line with the priori expectations.

Inflation, one of the determinants of macroeconomic instability, is found to be negative and significant in the long run as determined by Najia et al. (2013). In the short run, a positive significant effect on economic growth with one period lag is observed. The estimated coefficients of the long run relationship show that trade openness have positive sign and highly significant effect on economic growth both in short and long run as found in Usman (2012). These results show that trade openness leads to economic growth both in short and long run. The Foreign direct investment has a negative and significant effect on economic growth in the long run (Usman, 2012). The external debt (ED) also has a negative and significant effect on economic growth both in short and long run.

The study has an important policy implication that government should encourage the investment activities in energy sector to meet the rising energy demand which in turn stimulates economic growth. Thus, policy makers should initiate institutional reforms which can to mobilize both the public and the private sector resources to meet the required energy efficiency investment. The most obvious accompanying measures which the government could introduce are the dissemination of information. The government could also remove budgetary constraints, for instance by introducing subsidies on efficient equipment. The success of such efforts not only would affect Pakistan's own long-term prospects, but also the environment. Since an aggregate analysis is unable to provide guidelines to policymakers in designing a comprehensive sector-wise policy. A sectoral analysis should be conducted.

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