Journal of Public Value and Administrative Insight
Journal Homepage: http://readersinsight.net/JPVAI

Research Article

Substitution possibilities of energy and non-energy factors in Pakistan: A trans-log production function approach

Rubina Ilyas[1], Malik Saqib Ali[2], Syed Arshad Ali Shah[3]*

[1,2]Department of Economics, NUML, Islamabad, Pakistan
[3]Department of Management Sciences & Commerce, Bacha Khan University, Charsadda, Pakistan

*Corresponding Author email: arshad@bkuc.edu.pk

Submitted: 15 October 2021 *Revised: 10 January 2022* *Accepted: 17 January 2022*

ABSTRACT

Pakistan meets nearly one-third of its energy needs through imported energy resources i.e. coal, oil and Liquefied Natural Gas (LNG). Despite significant investments in energy infrastructure (especially in power generation projects), Pakistan continues to be energy insecure. This study attempts to analyze the substitution possibilities within energy sources, and between energy and non-energy factors by using a trans-log production function. The results show positive substitution between labor-energy and capital-energy which means improved skills and knowhow could result in energy conservation. Moreover, substitution of oil by gas in Pakistan will be highly encouraging as such substitution will address the issue of heavy import bill.

Keywords: *Energy Substitution; Trans-log Production Function; Energy Conservation*

1. INTRODUCTION

Pakistan's energy sector is poorly managed with extensive power and gas theft. Consequently, power shutdowns are common which not only affects the quality of life but it also impedes development of the country. During the past few decades, Pakistan went through severe power and gas shortages. Unable to meet its energy demand with the existing generating capacity, Pakistan still has to pay heavily for the import of energy (Malik et al., 2020). Currently 38% of the country's energy requirements are fulfilled by imported energy (Pakistan Economic Survey, 2020). The existing energy mix of Pakistan is highly reliant on gas, oil and expensive fuels instead of coal and hydel. The dependence on imported oil which is about 85% of the total supply is not only making the energy mix unfavorable but is also adding to the fiscal burden. Besides causing a drainage of its foreign exchange reserves, it makes the economy vulnerable to international energy price shocks which raises the risk of inflation (Yaqoob et al, 2020). The import of petroleum products contributed to the import bill by 17% in 2019. As international oil prices remained high in 2018, the cost of imported energy escalated by 25% ($13.3 billion) raising the contribution of imported energy to 37% in the import bill. During 2019, Pakistan imported 6.6 million tons of oil from the international market which worth a valuing of 3.4 billion USD.

https://doi.org/10.31580/jpvai.v4i4.2351
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Successive energy policies have focused on the expansion and diversification of the energy system through installation of new energy projects, yet the production capacity fails to fulfill the energy needs. The government of Pakistan has invested around $34 billion in the power sector with an aim to enhance the power production capacity. Resultantly, after a long period of power generation shortages, the power generation capacity has become more than sufficient to meet the total demand in the country. The power generation capacity of Pakistan was increased by 13,298MW during the phase of 2016-21 (NEPRA, 2020). However, in order to utilize this increased capacity there is a need of efficient T& D network to transmit electricity to the load centers. There are a number of constraints in the existing T & D network of NTDC which cause underutilization of the efficient plants. Another impediment that causes successful transmission of electricity is the policy of power outages adopted by DISCOs despite the availability of sufficient generating capacity. Due to these inefficiencies in the power system, consumers are still facing power outages in addition to the high tariffs of electricity. There is a persistent shortfall in the country during peak hours. Investments in T & D infrastructure are far less than the investments made to increase generation capacity. More than one-fourth of electricity generated is lost due to ruined network, theft, and insufficient energy accounting. The transmission network allows only 23000 MW-peak, with loss levels of close to 3 percent. About 10GWh of generation cannot be evacuated due to system constraints (ADB, 2019). The vocal idea of carrying out of this study is to scratching the substituting possibilities of the energy and non-energy components for the Pakistan economy.

2. LITERATURE REVIEW

Having been reviewed the empirical and theoretical literature, substitution possibilities of energy sector comes up as substantial issue. The unserved energy due to power outages has caused an industrial output loss that is estimated to fluctuate from 12% to 37%, for four major industrial cities of Punjab[1] (Siddiqui et al., 2010). These shortfalls have not only increased the production cost of firms due to alternative energy arrangements but also have caused delay in meeting supply commitments. The supply shortage was estimated to exceed more than 7,000 MW in 2015 (National Transmission and Dispatch Company, NTDC). Due to the escalating demand of electricity, there has been increase in the thermal generation of electricity in addition to hydro projects (Siddiqui, 2004; Khan and Ahmed, 2008; Qasim & Kotani 2014). Electricity generation through thermal projects has increased to 65 % of total power generation which has not only exposed the country to international oil price shocks but also has become a source of environmental degradation due to CO_2 emission. The cost of power generation has increased substantially due to fluctuations in the prices of international oil. The thermal generation of power makes use of furnace oil which is not only expensive but also has to be imported. In the course of the previous 7 years the price of furnace oil has witnessed an increase of 60 % exerting pressure on Pakistan's external account. Successive governments have been reluctant in passing the burden of costly power production to users by providing power subsidies that has resulted

[1] Gujrat, Faisalabad, Gujranwala, and Sialkot

in high circular debt (Malik, 2012). In order to maintain tariffs below the tariff rate notified by NEPRA (National Electric Power Regulatory Authority), the government has to allocate a significant portion of the budget (Rs. 3.1 trillion) for subsidies which is not only unaffordable but also diverts resources from other priorities.

Power generation consumed almost 37% of the primary energy supplies during the course of 2018-19. Over 55% of the primary energy used for electricity was lost during generation and another 7% in transmission and distribution. Generation losses tend to be high in thermal power plants (oil, gas and coal), ranging from 40% to 60%. Electricity needs of Pakistan are fulfilled from thermal, hydel, renewables and nuclear resources with some imports from Iran for an isolated region of Baluchistan. Whereas some of these losses are due to Pakistan's degraded power generation assets, these are typically the level of energy losses observed in thermal power plants worldwide due to technological and operational limitations (Lin & Raza, 2020). The energy needs are expected to increase three folds by 2050 while the supplies are not very inspiring. The rampant energy crisis gives rise to the need of technical advancement in the form of substitution (inter fuel and inter factor) which is suggested by many researchers and policy makers (Alessandro et al., 2010).

Inter fuel and inter factor substitution holds great importance to evaluate sustainability options through its impact on energy demand, fuel prices and also the growth of output. Hence, analyzing the substitution possibilities among different energy sources is necessary. This study aims to examine the possibility of substitution between energy(electricity, natural gas and petroleum products) and non-energy (capital and labor) input factors in order to cope with supply shortfalls and give policy recommendations for energy security. Considering how the rise in international oil prices has made the energy production so costly specifically the thermal generation of power using expensive imported furnace oil in the recent years, this study tries to suggest possible technological approaches to meet the energy requirements by examining the extent of inter-fuel and inter-factor substitution. The literature on substitution possibilities among factor inputs is very limited (Khan (1989), Chishti & Mahmood (1991), Khan & Rafiq (1993), Chaudhary et al. (1999), and Khan & Burki (2000) in case of Pakistan. These studies have examined the possibilities of inter factor substitution using energy, labor and capital as factor inputs. These studies aimed at the removal of allocative inefficiencies which create over and underutilization of factor inputs relative to their factor endowments. However, these studies have not addressed the possibility of inter fuel substitution.

Considering how the rise in international oil prices has made the energy production so costly specifically the thermal generation of power using expensive imported furnace oil in the recent years, there is a need to analyze the substitution possibilities for thermal electricity as well. This study tries to suggest possible technological approaches to meet the energy requirements by examining the extent of inter-fuel and inter-factor substitution. It is not sustainable for Pakistan to feed its energy requirements through imported thermal fuels, more than half of which tend to be lost during generation and transmission (Lin & Raza, 2020). For this purpose this study uses a trans-log production function for the estimation of substitution elasticities between capital, labor, electricity (thermal and hydro), petroleum and gas after estimating their output elasticities covering

the period 1980-2019. The output elasticities will provide useful information for economic growth by determining the critical inputs. Estimating the substitution elasticities will help to substitute the less costly inputs in order to conserve energy.

The rest of the study is organized as follows: Section 3 discusses the energy situation in Pakistan, Section 4 discusses the theoretical framework, methodology and data used and Section 5 delves into the results while Section 6 concludes the study.

3. OVERVIEW OF PAKISTAN ENERGY SECTOR

Over the last decades, the Pakistan has been facing severe energy crisis due to insufficient energy production to fulfill the escalating demand. The energy supply has increased by more than 40 times during the past 25 years and yet the demand outweighs the supply. The phenomenal growth of energy consumption is caused by the increased economic activities and growth of industrial, agriculture and service sectors along with the increasing population. Early in 1950's, Pakistan energy situation was shaped by successive discoveries of natural gas reserves. This led to the growth of large public sector gas distribution utilities. Most of the major power plants and domestic fertilizer industries were based on natural gas. The share of natural gas was approximately 50% during 2005. In the absences of any additions to the gas fields, gas production has plateaued. Major share of the energy demand burden is now on imported oil. Recently, the declining share of domestic gas supplies are being offset by imported LNG and coal (Malik et al., 2020). During 2017-18, total energy supplies consisted of 35% indigenous gas and 31% of oil. The demand supply gap has further widened by the inefficient use and wastage of energy resources (Fig. 1).

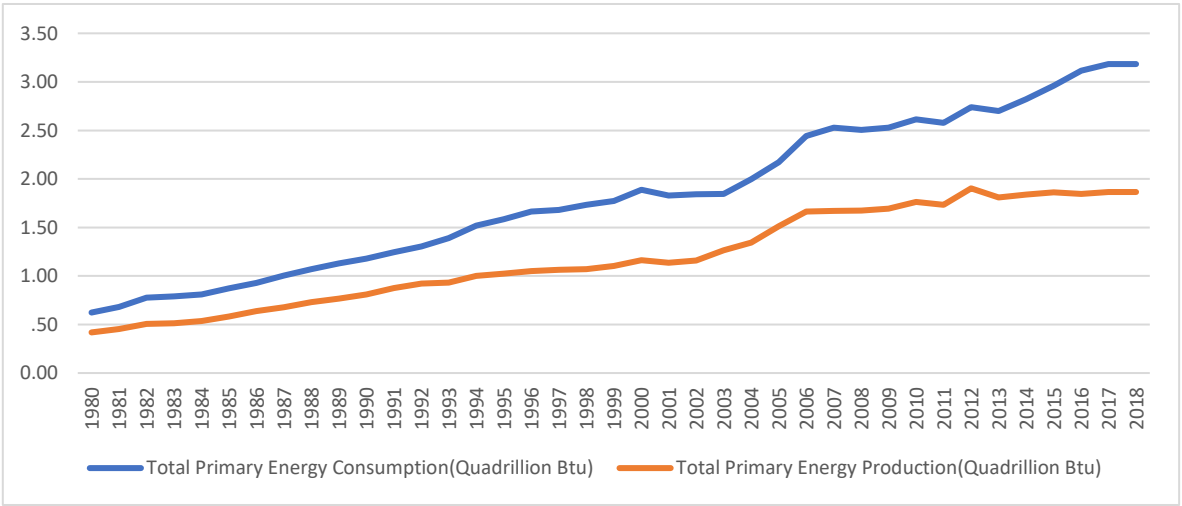


Fig. 1. Supply and Demand gap of primary energy of Pakistan

Source: IEA, 2019, Note: quad=10^{15} BTU (British Thermal Unit)

In 2017, primary energy (coal, natural gas, nuclear, hydro, bio fuels and waste, oil, wind and solar energy) consumption for Pakistan was 3.18 quadrillion btu. Primary energy consumption of Pakistan increased from 1.73 quadrillion btu in 1998 to 3.18 quadrillion btu in 2018 growing at an average annual rate of 4.19%. While, the production of primary energy was 1.86 quadrillion btu. Primary energy production of Pakistan increased from 1.07

quadrillion btu in 1998 to 1.86 quadrillion btu in 2018 growing at an average annual rate of 3.69%.

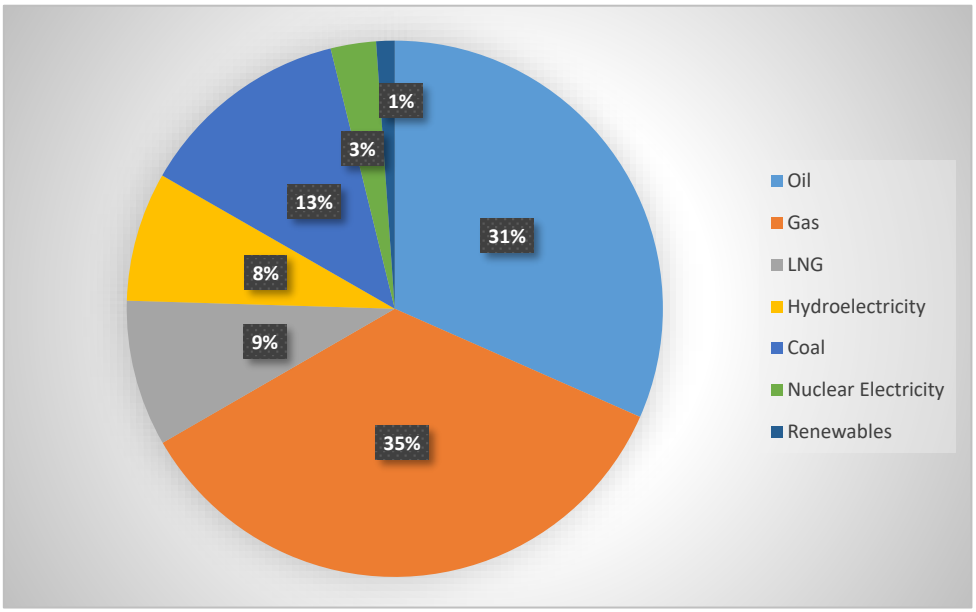


Fig. 2. Energy Mix of Pakistan 2018-19

Source: Pakistan Economic Survey 2018-19

The energy generation of Pakistan relies greatly upon oil and gas that attributes to 77% of total energy produced. In terms of energy mix, the dependence on oil has declined to 31.2% in the FY2018, which was recorded as 43.5% in the period 1998-2001 (Fig. 2). The share of hydroelectricity has reduced to 7.7% in 2017-18 which was 13.1% in 1998. Although the declining share of oil has reduced the fiscal burden, as a result of shortsightedness of policy makers, the successive administrations have failed to increase the hydro power generation. The dependence upon natural gas which was the highest in FY2006 (50.4%) has now reduced to 34.6% in the FY2018. This decline in the energy mix s due to the exhausting reserves of natural gas in addition to the restricted consumption by the transport sector and the usage of Liquid Natural Gas (LNG) since 2015 which has increased to 8.7% in 2018 (Pakistan Economic Survey 2018-19). The share of coal has increased to 12.7 percent and that of nuclear electricity gradually improved to 2.7% which was 0.2% in 1997.

Despite being sufficient in gas supply Pakistan is also facing gas crisis in addition to electricity crisis. Before 2006, the local resources have fulfilled the demand of the domestic as well as the commercial and industrial consumers with an ample supply. The growth rate of as consumption increased rapidly during 2015-16 while the growth rate of production was 1.2%. The shortfalls of gas supply have leaded to gas load shedding and supply cuts especially in the winter seasons. The severity of this shortfall can be assessed by the decision of the government implementing load shedding of two days per week on CNG stations and industries since November 2009 to March 2010 (Hhan et al., 2012). If this trend of gas consumption continues, the supply and demand gap will rise by 80 time till 2030 (Hye & Riaz, 2008).

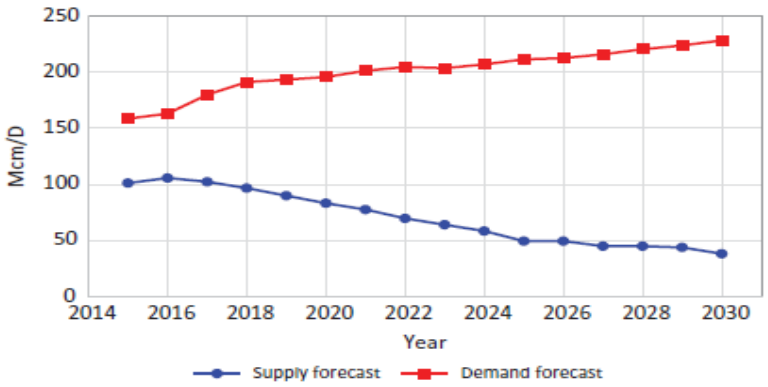


Fig. 3. Demand and Supply of Natural gas (indigenous)

Source: OGRA, 2017

The energy sector has undergone several changes in the past decade as a result of increasing energy demand. Significant changes have been made in the energy mix in the past 27 years. The share of oil accounted for 46 percent in 1990-91 which has reduced to 31 percent in 2017-18. The oil consumption has reduced during the past few years but still it accounts for a large share in the total energy consumed. Due to the limited refining capacity present in the country only 18 percent of the demand for petroleum products is fulfilled by domestic sources while the remaining 82% is fulfilled by import of crude oil from Middle East exporters[2]. Therefore the fluctuations in the international oil prices influence the oil prices in the local markets. Oil prices have constantly increased since the year 2003, with a maximum of $100 per barrel in the end of 2007. Pakistan's electricity generation cost is also influenced by the international oil prices as 65 percent[3] of the total electricity is generated by thermal sources. Thermal power is produced with coal, furnace oil, diesel and gas. The thermal plants make usage of furnace oil which is imported and due to a rise in oil prices it has become costly in the recent past[4] leading to a decline in thermal generation as shown in Fig. 4.

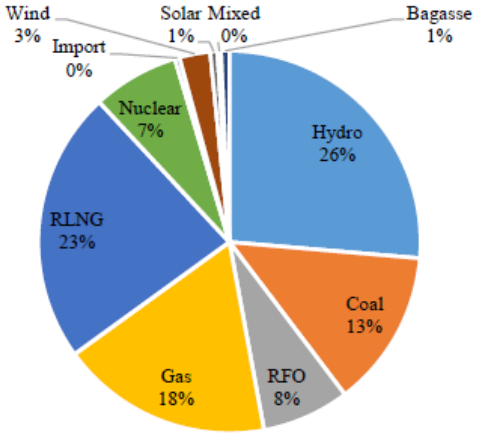


Fig. 4. Electricity generation by source (% share).

Source: Pakistan Energy Yearbook (2019)

[2] Ministry of Petroleum and Natural Resources (MPNR)
[3] Ministry of Energy, Hydrocarbon Development Institute of Pakistan (HDIP),2019
[4] "Ten Year Perspective Development Plan 2001-11 and Three Year Development Program" Planning Commission.

Power shortage has become a challenge for Pakistan. For almost a decade, the power crisis is prevailing in the country resulting in routine power outages, called “load shedding” in both urban and rural areas. Since 2007, the electricity supply shortfalls (5000-5500MW) have led to load shedding of long hours which in some areas has even averaged up to 17 hours per day. Despite having an increase of 13,298 MW in the power generation capacity there is a persistent shortfall in the country during peak hours (Fig. 5).

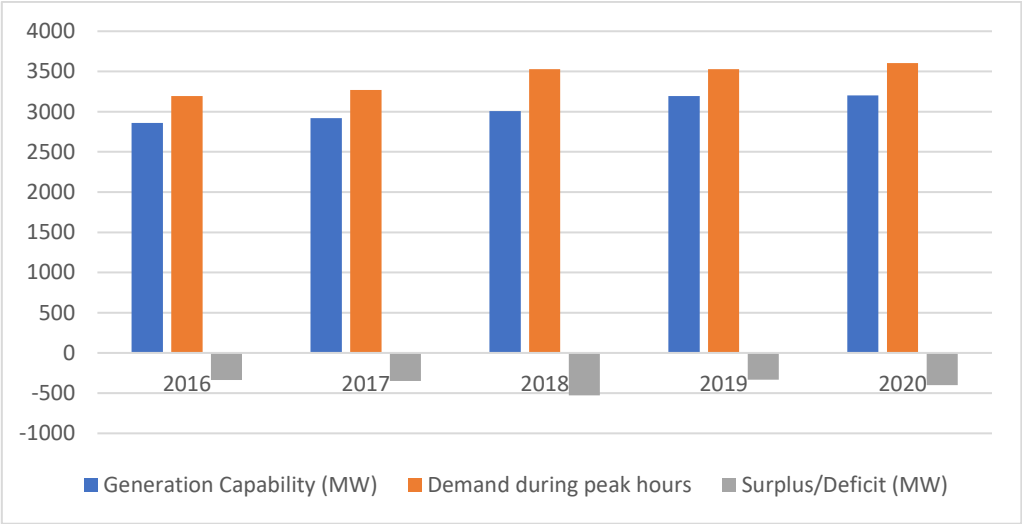


Fig. 5. Peak demand, the capability of electricity generation and shortfall (MW).

Source: State of Industry Report, NEPRA (2020)

Projection for the demand and supply of electricity has been depicted in Fig. 6. It is evident that there is continuous increase in the demand for electricity with an annual growth rate of 5-7%. In the hours of power cuts most households use gas fueled generators which adds to the inefficient use.

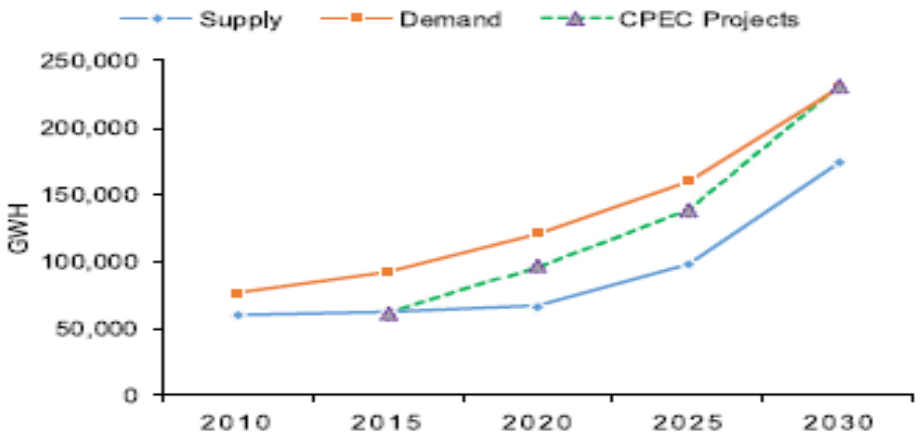


Fig. 6. Projected supply and demand of electricity

Source: Iqbal et al., 2018

The projection of electricity supply is shown by the green curve incase if the energy projects under the CPEC program are completed on time (Irfan et al., 2020). The government of Pakistan has invested around $34 billion in the power sector with an aim to enhance the

power production capacity. However, the energy crisis in Pakistan is not just a predicament of supply shortages rather it is manifold; including supply side as well as demand side issues.

4. THEORETICAL FRAMEWORK, EMPIRICAL SPECIFICATION AND DATA

The data on GDP, labor, capital stock, oil, electricity, natural gas consumption, and prices of various energy sources in Pakistan for the period 1980-2019 is taken from various issues of Energy Year Book (various issues), National Electric Power Regulatory Authority (NEPRA) and Pakistan Economic Survey (various issues)[5]. The data on the gross capital of Pakistan's economy has been taken from the Penn World Tables with updating the whole series of data up to the last observation following a similar technique. This variable has been constructed by means of the Perpetual Inventory Method of calculation at constant prices (2000=100) in this fashion:

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

In this equation Kt is the gross capital stock in year t, Kt−1 is the gross capital stock of the previous year, δ is the depreciation rate of capital which is assumed to be 4% and It is the gross domestic investment in year t. The initial year gross capital stock was calculated using the following formula:

$$K_0 = \frac{I_0}{g + \delta} \quad (2)$$

Where K_0 represents the base year gross capital stock and Io denotes the capital expenditures in the base year and signifies the average growth rate of capital expenditures over the sample period.

4.1. ENERGY INPUT AND SUBSTITUTION

In order to estimate the substitution possibilities between input factors studies such as (Adeyemo et al., 2007, Ma et al., 2008 and Penphanussak and Wongsapai, 2008), have made use of the trans log cost given by Berndt and Christensen (1973). The trans log functional form is more flexible in the sense that it allows the elasticities of substitution to change according to the share of fuels. The cost function is given as:

$$C = (Pk, Pl, PE, PM, Q) \quad (3)$$

This cost function can be represented by a trans log cost function as:

$$lnC = \alpha_0 + \sum_{i=1}^{n} \alpha_1 lnP_i + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{m} \gamma_{ij} lnP_i lnP_j + \alpha_y lnY_i + \frac{1}{2}\gamma_{yy}(lnY)^2 + \sum_{i=1}^{n} lnP_i lnY \quad (4)$$

[5] Both are published by government of Pakistan.

where i, j = 1... N are different inputs, C is total cost, Y is output and the P,'s are the prices of the factor inputs. After solving for cost minimizing input demand equations the elasticity for substitution can be obtained for different factor inputs.

However, the price data of input factors is not available in many cases. In such a case other studies have employed the trans-log production function. Moreover, the trans-log production function represent in fact a class of flexible functional form for the production functions. One of the main advantages of the respective production function is that, unlike in case of Cobb Douglas production function, it does not assume rigid premises such as: perfect or "smooth" substitution between production factors or perfect competition on the production factors market (Klacek, et al., 2007). Also, the concept of the trans-log production function permits to pass from a linear relationship between the output and the production factors, which are taken into account, to a nonlinear one. Due to its properties, the trans-log production function can be used for the second order approximation of a linear-homogenous production, the estimation of the Allen elasticities of substitution, the estimation of the production frontier or the measurement of the total factor productivity dynamics (Pavelescu, 2011).

Following Wesseh and Lin (2013), trans log production function has been used as the data for factor prices is not available in case of Pakistan.

The general form of the production function is given under:

$$Y_t = f(K_t, L_t, P_t, G_t, E_t) \tag{5}$$

Where Yt represents output, Kt capital stock, Lt labor, Pt petroleum, Gt natural gas and E_t electricity consumption. The trans-log production function is given as:

$$\begin{aligned} \ln Y_t = \alpha &+ \beta_k \ln K_t \\ &+ \beta_l \ln L_t \\ &+ \beta_p \ln P_t \\ &+ \beta_g \ln G_t + \beta_e \ln E_t \\ &+ \beta_{kl} \ln K_t \ln L_t \\ &+ \beta_{kp} \ln K_t \ln P_t \\ &+ \beta_{kg} \ln K_t \ln G_t + \beta_{ke} \ln K_t E_t \\ &+ +\beta_{lp} \ln L_t \ln P_t + \beta_{lg} \ln L_t \ln G_t + \beta_{le} \ln L_t E_t + + \beta_{pg} \ln P_t \ln G_t + \beta_{pe} \ln P_t E_t \\ &+ +\beta_{kk} (\ln K_t)^2 + \beta_{ll} (\ln L_t)^2 + \beta_{pp} (\ln P_t)^2 + \beta_{gg} (\ln G_t)^2 + \beta_{ee} (\ln E_t)^2 \end{aligned} \tag{6}$$

Differentiating equation (4) with respect to the natural log of Kt, Lt, Pt, Gt and Et, the output elasticity is generated with respect to the input used:

$$\varphi K = \frac{dY/Y}{dK/K} = \frac{d \ln Y_t}{d \ln K_t} = \beta_k + \beta_{kl} \ln L_t + \beta_{kp} \ln P_t + \beta_{kg} \ln G_t + 2\beta_{kk} \ln K_t \tag{7}$$

$$\varphi L = \frac{dY/Y}{dL/L} = \frac{d \ln Y_t}{d \ln L_t} = \beta_L + \beta_{kl} \ln K_t + \beta_{lp} \ln P_t + \beta_{lg} \ln G_t + 2\beta_{ll} \ln L_t \tag{8}$$

$$\varphi P = \frac{dY/Y}{dP/P} = \frac{d \ln Y_t}{d \ln P_t} = \beta_P + \beta_{kP} \ln K_t + \beta_{lp} \ln L_t + \beta_{Pg} \ln G_t + 2\beta_{PP} \ln P_t \tag{9}$$

$$\varphi G = \frac{dY/Y}{dG/G} = \frac{d\ln Y_t}{d\ln G_t} = \beta_G + \beta_{kG}\ln K_t + \beta_{lG}\ln L_t + \beta_{Pg}\ln P_t + 2\beta_{GG}\ln G_t \quad (10)$$

$$\varphi E = \frac{dY/Y}{dE/E} = \frac{d\ln Y_t}{d\ln E_t} = \beta_E + \beta_{ke}\ln K_t + \beta_{le}\ln L_t + \beta_{Pe}\ln P_t + 2\beta_{ee}\ln E_t \quad (11)$$

The elasticity of substitution measures percent change in one input factor due to the percent change in marginal rate of technical substitution. In other words it illustrates how the substitution among input factors changes with the change in the price of one factor input. The elasticity between labor and capital is given as:

$$\sigma_{KL} = \frac{d(\frac{K}{L})}{(\frac{K}{L})}\left[\frac{d(\frac{MPP_L}{MPP_K})}{(\frac{MPP_L}{MPP_K})}\right]^{-1} = \frac{d(\frac{K}{L})}{d(\frac{MPP_L}{MPP_K})}\cdot\frac{(\frac{MPP_L}{MPP_K})}{(\frac{K}{L})} \quad (12)$$

MPPK is the marginal physical productivity of capital and MPPL is the marginal productivity of labor.

$$\frac{MPP_l}{MPP_K} = \frac{\partial Y/\partial L}{\partial Y/\partial K} = \frac{\varphi_L}{\varphi_K}\cdot\frac{K}{L} \quad (13)$$

Combining (12) and (13), we get equation (14)

$$\sigma_{KL} = \frac{d(\frac{K}{L})}{d(\frac{MPP_L}{MPP_K})}\cdot\frac{\varphi_L}{\varphi_K} = \frac{\varphi_L}{\varphi_K}\cdot\left[\frac{d(\frac{MPP_L}{MPP_K})}{(\frac{MPP_L}{MPP_K})}\right]^{-1} = \frac{\varphi_L}{\varphi_K}\cdot\left[\frac{d(\frac{\varphi_L K}{\varphi_K L})}{d(\frac{K}{L})}\right]^{-1} \quad (14)$$

We also know that

$$\frac{d(\frac{\varphi_L K}{\varphi_K L})}{d(\frac{K}{L})} = \frac{\varphi_L}{\varphi_K} + \frac{K}{L}\cdot\frac{d(\frac{\varphi_L}{\varphi_K})}{d(\frac{K}{L})} \quad (15)$$

$$d\left(\frac{\varphi_L}{\varphi_K}\right) = -\frac{\varphi_L}{\varphi_K}.d\varphi_K + \frac{1}{\varphi_K}d\varphi_L \quad (16)$$

$$d\left(\frac{K}{L}\right) = -\frac{K}{L^2}.dL + \frac{1}{L}dK \quad (17)$$

Putting (15) to (16) and (17) together we get equation (18) which gives substitution elasticity between capital and labor.

$$\sigma_{KL} = \left[1 + \left[-\beta_{kl} + \frac{\varphi_K}{\varphi_L}.\beta_{ll}\right](-\varphi_K + \varphi_L)^{-1}\right]^{-1} \quad (18)$$

Similarly we get substitution elasticities between other input pairs;

$$\sigma_{KP} = \left[1 + \left[-\beta_{kP} + \frac{\varphi_K}{\varphi_P}.\beta_{PP}\right](-\varphi_K + \varphi_P)^{-1}\right]^{-1} \quad (19)$$

$$\sigma_{KG} = \left[1 + \left[-\beta_{kG} + \frac{\varphi_K}{\varphi_G}.\beta_{GG}\right](-\varphi_K + \varphi_G)^{-1}\right]^{-1} \quad (20)$$

$$\sigma_{KE} = \left[1 + \left[-\beta_{ke} + \frac{\varphi_K}{\varphi_e}.\beta_{ee}\right](-\varphi_K + \varphi_e)^{-1}\right]^{-1} \quad (21)$$

$$\sigma_{LP} = \left[1 + \left[-\beta_{LP} + \frac{\varphi_L}{\varphi_P}.\beta_{PP}\right](-\varphi_L + \varphi_P)^{-1}\right]^{-1} \quad (22)$$

$$\sigma_{LG} = \left[1 + \left[-\beta_{LG} + \frac{\varphi_L}{\varphi_G}.\beta_{GG}\right](-\varphi_L + \varphi_G)^{-1}\right]^{-1} \quad (23)$$

$$\sigma_{Le} = \left[1 + \left[-\beta_{Le} + \frac{\varphi_L}{\varphi_e}.\beta_{ee}\right](-\varphi_L + \varphi_e)^{-1}\right]^{-1} \quad (24)$$

$$\sigma_{PG} = \left[1 + \left[-\beta_{PG} + \frac{\varphi_P}{\varphi_G}.\beta_{GG}\right](-\varphi_P + \varphi_G)^{-1}\right]^{-1} \quad (25)$$

$$\sigma_{Pe} = \left[1 + \left[-\beta_{Pe} + \frac{\varphi_P}{\varphi_e}.\beta_{ee}\right](-\varphi_P + \varphi_e)^{-1}\right]^{-1} \quad (26)$$

$$\sigma_{Ge} = \left[1 + \left[-\beta_{GE} + \frac{\varphi_G}{\varphi_E}.\beta_{eE}\right](-\varphi_G + \varphi_E)^{-1}\right]^{-1} \quad (27)$$

4.2. Econometric Methodology

Using the trans-log production function, a large number of explanatory variables are estimated. There are high chances of presence of multicollinearity by using the ordinary least square (OLS) due to the linear association among the explanatory variables. It will not only increase the variance of the estimates but also make them inefficient. To avoid the threat of multicollinearity, the linear relationship has been examined in the explanatory variable following Lin and Fei (2015). The results of show that there is high correlation present among the explanatory variables. In such a case applying OLS technique will give biased results. In order to obtain efficient estimates the ridge regression has been utilized which is based on the linear regression equation given as:

$$Y = \alpha + \beta^T X \quad (28)$$

However, in order to obtain the estimates of $\beta_i (i = 1,2,3 \ldots m)$, the regression equation is modified as:

$$Y = X\beta + \varepsilon \quad (29)$$

Here X is based on sample data which by assumption is symmetric positive definite. The error vector is assumed to be normally distributed $(0,\sigma^2 I_n)$. The OLS unbiased estimate of $\beta$is then given as:

$$\beta = (X^T X)^{-1} X^T Y \quad (30)$$

Where the correlation matrix is given by R=$X^T X$. While the variance-covariance matrix is given as $\text{Var}(\beta) = \sigma^2 R^{-1}$. By expansion we get,

$$\mathrm{Var}(b_j) = r^{jj} = \frac{1}{1-R_j^2} \tag{31}$$

Where R is obtained by regressing Xj on other explanatory variables. Ridge regression has been used in recent literature in order to solve the problem of multicollinearity. It adds a value k (which is assumed to be bounded above zero) to the diagonal elements of the correlation matrix which are in a form of ridge and is given as:

$$\bar{\beta} = (R + kI)^{-1} X^T Y \tag{32}$$

Where k=0,1,2...n. k mostly lies between 0 to 1 however its appropriate value on the true regression coefficients. Table 1. Describes all the variables used in the study.

Table 1. Description of variables

Variable	Unit	Component
Gross output	$10 billion	Total value added
Labor employed	10,000,000 persons	Total labor force
Gross capital stock	$100 billion	Gross capital formation
Petroleum consumption	Quadrillion BTU	Crude oil, LPG, coke, asphalt, lubricants, gasoline, aviation, gasoline, etc.
Natural gas consumption	Quadrillion BTU	Total natural gas
Electricity consumption	Quadrillion BTU	Total electric power

5. EMPIRICAL RESULTS

Based on the ridge trace plot given in Fig. 7, the value of ridge penalty is determined at 0.55. This is the point where all of the parameters of the model are stabilized. The output elasticities and the respective elasticities of substitution are estimated by using the ridge penalty of 0.55. The results of the ridge regression are presented in Table 2.

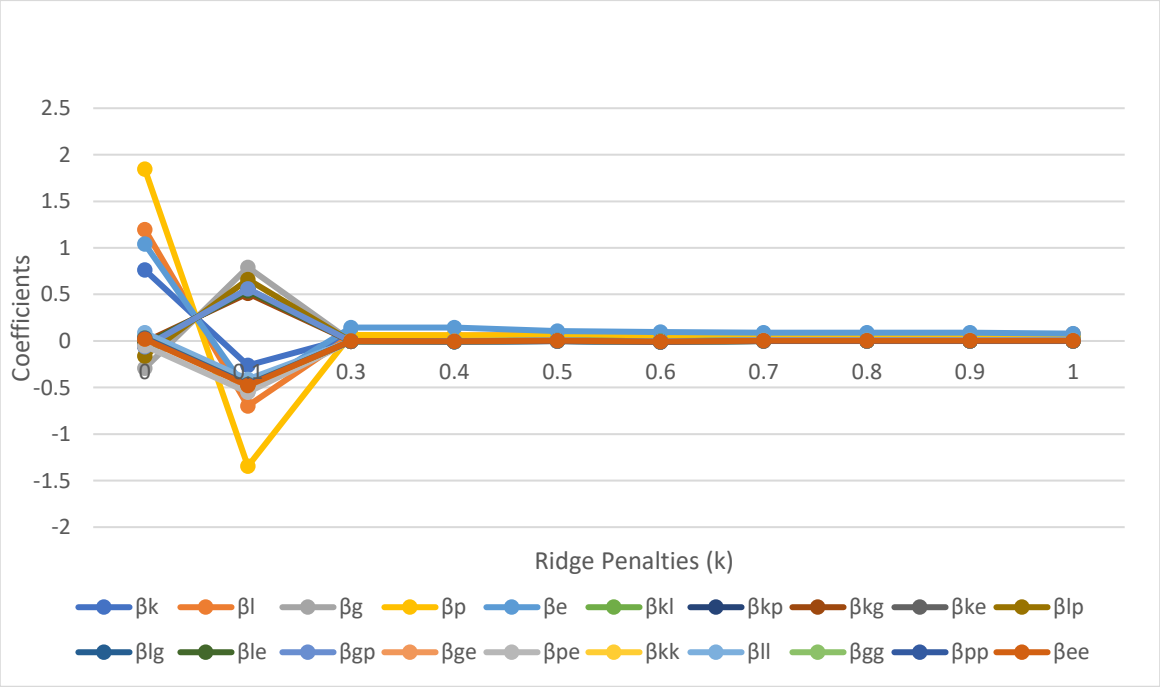


Fig. 7. Ridge trace plot of the coefficient estimates

Table 2, shows the results of the ridge regression which are statistically significant. The mode is considered to be reasonable as indicated by all the testing indicators such as the value of F-statistics which shows the significance level of regression equation, the Adjusted R-Square (goodness of fit) and the standard error of estimates

Table 2. Results of the Ridge Regression Model

ANOVA table			
	Df	**SS**	**MS**
Regression	14	32.016	2.287
Residual	20	2.9840	0.149
F-Value	15.327		
Sig F	0.0		
Ridge Regression with k = 0.55			
Multiple R = 0.958			
R Square = 0.918			
Adjusted R Square = 0.860			
Variables in Equation	**Coefficients**	**Standard errors**	**P-Value**
lnK	0.1482094	0.0084373	0.014
lnL	0.1440003	0.0063241	0.004
lnG	0.1308127	0.0093594	0.000
lnP	0.1402792	0.0130334	0.017
lnE	0.1507603	0.0076383	0.005
lnK-lnL	0.1469652	0.0072687	0.013
lnK-lnP	0.1500965	0.0059945	0.008
lnK-lnG	0.1436003	0.0061561	0.014
lnK-lnE	0.1513145	0.0031089	0.002
lnL-lnP	0.1450138	0.0045094	0.000
lnL-lnG	0.1396537	0.0050087	0.029
lnL-lnE	0.1464642	0.0037510	0.004
lnP-lnG	0.1369868	0.0061551	0.001
lnP-lnE	0.1463416	0.0071791	0.000
lnG-lnE	0.1430993	0.0063999	0.029
lnK-lnk	0.1501109	0.0090934	0.018
lnL-lnL	0.1432938	0.0071408	0.000
lnP-lnP	0.1383067	0.0130065	0.006
lnG-lnG	0.1294845	0.0095468	0.025
lnE-lnE	0.1463655	0.0069011	0.003

The application of the ridge regression has solved the problem of multicollinearity as shown by the standard errors of all the coefficients which are measured to be less than 0.02. The regression coefficients are also consistent with the economic theory which is indicated by their positive signs. The coefficients of the cross variables and squared variables are also positive. These results indicate increasing returns to scale.

The output elasticities were estimated with the help of equation (5) to (9). The results shown in Table 3 indicate that all factor inputs have positive output elasticities with labor having the highest degree of responsiveness, followed by electricity and natural gas. This shows that over the years the consumption trend of these inputs has been increasing.

Table 3. Output Elasticities of Factor Inputs

Years	φK	φL	φG	φP	φE
1980	0.09	0.37	0.14	0.16	0.17
1981	0.09	0.37	0.14	0.17	0.18
1982	0.09	0.37	0.14	0.17	0.18
1983	0.09	0.37	0.14	0.17	0.18
1984	0.09	0.37	0.14	0.17	0.18
1985	0.09	0.37	0.14	0.17	0.18
1986	0.09	0.38	0.14	0.17	0.18
1987	0.10	0.38	0.14	0.17	0.18
1988	0.10	0.38	0.14	0.17	0.18
1989	0.10	0.38	0.14	0.17	0.18
1990	0.10	0.38	0.14	0.17	0.18
1991	0.10	0.39	0.14	0.17	0.19
1992	0.10	0.39	0.14	0.17	0.19
1993	0.10	0.39	0.14	0.17	0.19
1994	0.10	0.39	0.14	0.17	0.19
1995	0.10	0.39	0.14	0.17	0.19
1996	0.10	0.39	0.14	0.18	0.19
1997	0.10	0.39	0.15	0.18	0.19
1998	0.10	0.40	0.15	0.18	0.19
1999	0.10	0.40	0.15	0.18	0.19
2000	0.10	0.40	0.15	0.18	0.19
2001	0.10	0.40	0.15	0.18	0.19
2002	0.10	0.40	0.15	0.18	0.19
2003	0.10	0.40	0.15	0.18	0.19
2004	0.10	0.40	0.15	0.18	0.19
2005	0.10	0.41	0.15	0.18	0.20
2006	0.10	0.41	0.15	0.18	0.20
2007	0.10	0.41	0.15	0.18	0.20
2008	0.10	0.41	0.15	0.18	0.20
2009	0.10	0.41	0.15	0.18	0.20
2010	0.10	0.42	0.15	0.18	0.20
2011	0.11	0.42	0.15	0.18	0.20
2012	0.11	0.42	0.15	0.18	0.20
2013	0.11	0.42	0.15	0.18	0.20
2014	0.11	0.42	0.15	0.18	0.20
2015	0.11	0.42	0.15	0.18	0.20
2016	0.11	0.42	0.15	0.18	0.20
2017	0.11	0.42	0.15	0.18	0.20
2018	0.11	0.42	0.15	0.18	0.20
2019	0.11	0.42	0.15	0.18	0.20

Utilizing these estimates of output elasticities, the elasticities of substitution were computed using equation (18) to (27). The results presented in Table 4. Results show that all inputs are substitutes as the elasticities are positive and close to unity. These results are consistent with the earlier findings of Medina and Vega Cervera (2001), Smyth et al. (2011). Wesseh and Lin (2013). The substitution elasticity of capital and energy sources suggests that there is possibility of energy conservation with an increased use of energy saving technology. According to Tang and Tan, 2013, true energy prices will encourage the use of capital intensive methods in order to save more energy.

On the other hand these results also imply that Pakistan can shift its load of power generation from costly oil to natural gas as there is positive elasticity of substitution between them. However, due to the exhausting natural gas reserves, there is much need of price reforms of the energy items. The low prices of natural gas are constraining its supply (WB, 2015). After the removal of subsidies will result in competitive gas prices which will discourage inefficient gas consumption and increase gas reserves by encouraging fresh exploration. The substitution elasticity of labor and energy sources exhibits a positive trend over time. According to Mukherjee (2008), in order to substitute labor for energy the labor force has to be equipped with education and skills. This in turn will raise the labor productivity that will result in energy conservation by appropriate use of energy saving techniques (Mandal and Madheswaran, 2011).

Table 4. Inter factor and Inter Fuel Substitution Elasticities

Year	σ_{KL}	σ_{KG}	σ_{KP}	σ_{KE}	σ_{LG}	σ_{LP}	σ_{LE}	σ_{GP}	σ_{GE}	σ_{PE}
1980	0.9995	1.002334	1.002335	1.000439	0.998335	0.997125	0.998694	1.004633	0.991123	0.942135
1981	0.999595	1.002329	1.002324	1.000463	0.998349	0.997156	0.998679	1.004602	0.991269	0.944205
1982	0.999605	1.002316	1.002316	1.000487	0.998371	0.99718	0.998663	1.004589	0.991454	0.945852
1983	0.999615	1.0023	1.002307	1.000509	0.998395	0.997204	0.998647	1.004583	0.991652	0.947432
1984	0.999623	1.002284	1.002297	1.000531	0.998417	0.997229	0.998628	1.004574	0.99184	0.94913
1985	0.99963	1.002271	1.002284	1.000552	0.998436	0.997258	0.998609	1.004555	0.992014	0.950971
1986	0.999629	1.002259	1.002274	1.000569	0.998443	0.997269	0.998574	1.004541	0.992161	0.952418
1987	0.999651	1.002237	1.002256	1.00059	0.998487	0.997333	0.998592	1.004515	0.992369	0.954444
1988	0.999652	1.002222	1.002244	1.000605	0.998499	0.997349	0.998566	1.004501	0.992517	0.955768
1989	0.99966	1.002206	1.00223	1.00061	0.99852	0.997382	0.998575	1.004482	0.992619	0.95671
1990	0.999668	1.002192	1.002213	1.000618	0.99854	0.99742	0.998577	1.004455	0.99273	0.958008
1991	0.999674	1.002172	1.002197	1.000624	0.998563	0.997456	0.99858	1.004437	0.992855	0.959197
1992	0.999652	1.002158	1.002189	1.000625	0.998545	0.997426	0.99852	1.004433	0.99293	0.959614
1993	0.999656	1.002138	1.002174	1.000621	0.998564	0.997453	0.998534	1.004418	0.993007	0.960138
1994	0.999658	1.002117	1.00216	1.000615	0.998583	0.997476	0.998546	1.004408	0.993082	0.960601
1995	0.999651	1.002097	1.002147	1.000613	0.998591	0.997482	0.998533	1.004402	0.993167	0.961088
1996	0.999652	1.002077	1.002132	1.000607	0.998608	0.997507	0.998545	1.004388	0.993232	0.961626
1997	0.999667	1.002053	1.002113	1.000599	0.998647	0.997563	0.998593	1.004373	0.993314	0.962323
1998	0.999678	1.002034	1.002098	1.000588	0.998676	0.997606	0.998639	1.00436	0.99335	0.962645
1999	0.99968	1.002024	1.002086	1.00058	0.998685	0.997628	0.998658	1.004339	0.993356	0.962913
2000	0.999667	1.00201	1.00207	1.000575	0.998677	0.99763	0.99863	1.004314	0.9934	0.963597
2001	0.999666	1.001993	1.002049	1.000572	0.998689	0.997664	0.998633	1.004285	0.99346	0.964565
2002	0.999672	1.001977	1.002029	1.000567	0.998709	0.997709	0.998655	1.004256	0.993515	0.965483
2003	0.999672	1.001969	1.002005	1.000569	0.998714	0.997754	0.998651	1.004205	0.993558	0.966853
2004	0.99968	1.001957	1.001979	1.000571	0.998731	0.997811	0.998665	1.004153	0.993623	0.968166
2005	0.999679	1.001935	1.001958	1.000571	0.998746	0.997839	0.998661	1.004128	0.99372	0.969002
2006	0.9997	1.001897	1.001931	1.000568	0.998802	0.997915	0.998716	1.00411	0.993876	0.969978
2007	0.9997	1.00187	1.001916	1.000558	0.998823	0.997935	0.998732	1.004106	0.993952	0.970214
2008	0.999701	1.001847	1.0019	1.000538	0.998842	0.997961	0.998767	1.004098	0.993964	0.970253
2009	0.999706	1.001821	1.001882	1.000523	0.99887	0.997998	0.998805	1.004091	0.994013	0.970512
2010	0.999704	1.001797	1.001867	1.000518	0.998885	0.998015	0.998806	1.004088	0.99409	0.970942
2011	0.9997	1.001779	1.001853	1.000509	0.998894	0.998031	0.998811	1.00408	0.994124	0.971244
2012	0.9997	1.00176	1.001839	1.000495	0.998909	0.998052	0.998833	1.004072	0.994145	0.971385
2013	0.999696	1.001735	1.001828	1.00049	0.998923	0.998062	0.998833	1.004077	0.994223	0.971645
2014	0.999686	1.001709	1.00182	1.000461	0.998934	0.998063	0.998858	1.004106	0.994202	0.971257
2015	0.999683	1.001721	1.001803	1.00042	0.99892	0.998088	0.998918	1.004052	0.993982	0.970842
2016	0.999683	1.001957	1.001979	1.000571	0.998731	0.997811	0.998665	1.004153	0.993623	0.968166

Year	σ_{KL}	σ_{KG}	σ_{KP}	σ_{KE}	σ_{LG}	σ_{LP}	σ_{LE}	σ_{GP}	σ_{GE}	σ_{PE}
2017	0.999685	1.001935	1.001958	1.000571	0.998746	0.997839	0.998661	1.004128	0.99372	0.969002
2018	0.9997	1.001897	1.001931	1.000568	0.998802	0.997915	0.998716	1.00411	0.993876	0.969978
2019	0.9997	1.00187	1.001916	1.000558	0.998823	0.997935	0.998732	1.004106	0.993952	0.970214

6. CONCLUSION

This study has examined the possibility of inter factor and inter fuel substitution between the labor, capital and energy sources (electricity, natural gas and petroleum products). The ridge regression methodology has been applied due to the problem of multicollinearity present in the data. The positive output elasticities indicates that all the factors contribute towards economic growth. Moreover, positive substitution enhances the need of increased investment in efficient energy saving technologies. Moreover, the results also suggests substitution between labor and energy items which means improved skills and knowhow could result in energy conservation. Substitution of oil by gas in Pakistan will be highly encouraging as such substitution will address the issue of heavy import bill. These results are critically significant for saving energy, environmental sustainability, generating employment and especially for increasing power generation capacities. The results of this study can contribute a tremendous boost to future energy policy in Pakistan in the perspective of reducing the import bill with increased economic growth and enriched energy market in accordance with targets set in future policy document 2025. Since the fuels are substitutes hence, the government of Pakistan should concentrate on the preferred fuel to develop its policy of supporting alternative fuels and a diversified energy supply mix in consort with enriched economic as well as environmental growth.

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