Quantifying Oil Supply Security of Pakistan

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Abstract

This study aims to analyse the historical aspect and involvement of Pakistan's oil import dependency and supply security by the Principal Component Analysis (PCA) methodology to establish the Oil Supply Security index (OSSI) for 23 years from 1995 to 2017. In this study, there are seven factors consist in evaluating oil supply security of the country: Energy Structure (G1), Oil Intensity (G2), Gross inland Consumption (G3), Index of national economy dependency on oil (G4), Oil Price (G5), the diversity indices of Shannon Weiner and Herfindahl-Hirschman (G6) and (G7). The results of the PCA methodology represent the first four factors of Energy Structure (G1), Oil Intensity (G2), Gross Inland Consumption (G3), and Index of National Economy dependency on Oil (G4), significant contributors to the oil supply security index (OSSI) of Pakistan. Moreover, Oil prices (G5), the Diversity Indices of (G6) and (G7), have a minimum role in the overall OSSI of the country. Pakistan's OSSI showed low risk in 1998 and 2010 when it peaked, and the trend line declined after 1999 till 2006 showed high risk, then, showing towards an fluctuation in oil supply security.

Keywords: *Oil supply security; Diversification of oil; PCA methodology; Import dependency*.

1. Introduction

Energy is a valuable resource used to improve a person's quality of life in several ways. Many parts of life, such as transportation, industry, agriculture, household, and many more, are dependent on energy in some manner, either directly or indirectly. All conventional energy resources discovered on the earth, like crude oil, gas, and coal, and these resources are depleting at a faster rate due to their consumption need in rapid growth. On the other hand, these resources are not evenly supplied on the surface of the world, and therefore many countries import these resources in trade to balance their energy demands.

Energy security is defined as "the continuous availability of energy sources at appropriate prices (EIA)". At this moment, it is pointed out that arranging future energy utilization should consist of uncertainties involving energy demand. Alternatively, short-term energy security is concentrations on the energy structure's capability to respond in abrupt variations in the supply-demand balance.

Energy import reliance has been a significant aspect of the economy both for developed and developing economies that require energy security since the 1970s, there were several oil crises [1], [2]. The issue of significant reliance on foreign energy supplies is critical for emerging countries than in industrialized countries, but both need the energy to expand at a quicker rate. As a result, emerging countries are typically reliant on foreign oil [3]. The rising energy dependency most of countries on the industrialization and globalization of the energy industry support the notion that national energy security is impossible to accomplish. [4].

Pakistan is developing country economy, is the 33rd major oil user in the world and ranks 26th largest in terms of power purchasing party (PPP) in 2016 [6-7]. Pakistan net import dependency in primary energy surpassed 81% because of raising difference between domestic production and consumption in 2017 [7]. Pakistan reliant on imported energy sources which threat economy badly affected is noted by the Ministry, as well as by scholars [8]–[11].

Pakistan's dependency on fossil fuel imports is perilous for two reasons, firstly, due to limited indigenous oil resources, import dependence on oil and natural gas was 36% and 43%, respectively, in 2017. Furthermore, in 2005-2006, the biggest share of the energy mix was given to fossil fuels, with 28 percent to oil and 51 percent given to natural gas [12]. The diversity in Pakistan's source counties for energy import is the significant dimensions of its energy security especially for when calculating energy import risk because country has historically depended on a limited country.

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Afterwards, country started to import oil from other sources of countries. Since 1995, Romina has main supplier and Pakistan total import of oil has varied between 60% to 40%. United Arab Emirates provide around 60% of Pakistan's import in 2017, while Kuwait was second share around (14%) and Singapore was third share around (7%) respectively[13].

As a result, it is essential to realise the main dynamic of Pakistan's oil import strategy periods. The author of this article evaluates Pakistan's supply security which depend on different indicators relating to create an index called the "oil supply security index". While, Oil has a major part in the country's energy demand, estimating Pakistan's oil supply security is greater importance due to, unlike other fuels with natural gas and coal, oil consumption has been important share in energy mix, and escalating in the transport use particularly, oil becomes the main energy source in country's energy mix recently.

Concerns related to the Pakistan's with energy supply are expected to occupy the country's policy agenda for the immediate future, as consumption is estimated to grow exponentially while indigenous production would slightly significant [11]. According to Rehman et.al [14], they predicted that the economic sector's requirement would be the largest in 2035, followed by the transportation and home sectors. The findings also suggest that, under business-as-usual conditions, oil will be the most consumed energy form (38.16 percent), followed by natural gas (36.57 percent), electricity (16.22 percent), coal (7.52 percent), and LPG (1.52 percent) in 2035.Therefore, Pakistan should create and implement well-planned oil supply strategies to ensure one's own future energy supply security. In this study to estimate oil supply security like methodology as Ediger and Berk [15]. Principal Component Analysis (PCA) methodology to form a "Oil Supply Security Index" (OSSI) by using seven factors that are believed to affect oil supply security of Pakistan. We then calculate the historical development of the OSSI from 1995-2017.

There is vast amount of literature on index creation in energy security – related problems. Ang et al. [16], gives a complete review of the topic. According to Ang et al. [16], the three most used methodologies is forming a weighted index are using equal weights, using oil / import shares, and PCA methodology. While oil / import share methodology is related for multi-oil analyses. PCA is more to using equal weights, as the weights of the seven factors in the index are self-determined in PC

In this study, the linking between oil consumption and its driving factors is investigated using the PCA method. It consists set of 4 sections as follows: In section 1, overview energy security in worldwide and Pakistan, in section 2, the driving features of oil consumption are investigated by using the PCA method to evaluate the parameters. In section 3, found results are presented, and in the last section, the conclusion is presented

2. Methodology

This study constructed an index called oil supply security index (OSSI) for Pakistan using Principal Component Analysis (PCA). PCA is a technique used to create an index by choosing related indicator added to the index, computing a correlation matrix, eigenvalues, orthogonal rotation matrix-rotated component loadings, and finally score coefficients [17][18]. The technique employed in this study is resemblance with the study Ediger and Berk [15] and Edigar et.al. [3] Seven indicators are selected to evaluate the oil supply security of Pakistan of the period during1995 and 2017. These factors are the share of oil consumption in primary energy consumption (G1), the share of oil consumption in the GDP (G2), the share of oil consumption in the population (G3), the share of oil import in the GDP (G4), oil price proxy (G5) [15], and diversity in oil supplier countries (G6 and G7).

The following seven factors are selecting for oil supply security index as follow.

- Energy Structure (G_1)
- Oil intensity (G_2)
- Gross Inland Consumption (G_3)
- Index of National Economy Dependence on oil (G_4)
- Oil price proxy (G_5)
- Shannon -Wiener-Index (G_6)
- Herfindahl-Hirschman index. (G_7)

2.1. Energy Structure (G1)

The energy structure (ES) is the proportion of primary energy consumption to oil consumption in million tons of oil equivalent (MTOE).

$$G_{1_{(t)}} = \frac{\textbf{Oil Consumption (mtoe)}}{\textbf{Primary Energy Consumption (mtoe)}} \tag{1}$$

2.2. Oil Intensity (G2)

The oil intensity is defined as the ratio of net oil consumption to GDP. It is defined as follow:

$$\mathbf{G_{2_{(t)}}} = \frac{\mathbf{TC_{oil\ (t)}}}{\mathbf{GDP_{(t)}}} \tag{2}$$

Where TC oil (t) represents net oil consumption in fiscal year t (mtoe) and GDP represents GDP constant 2010 (US$) in fiscal year t. Commonly, Eq. (2) suggests that a country's net oil consumption should be smaller and indicating a lower oil intensity. As a result, oil intensity is measured in (mtoe), which is used to calculate the worth of a commodity in US dollars.

2.3. Gross Inland Consumption(G3)

Gross inland consumption (GIC) is defined as total oil consumption per capita; it is measure of energy efficiency of country. The GIC is defined as follow:

$$\mathbf{G_{3_{(t)}}} = \frac{\mathbf{TC\ oil\ (t)}}{\mathbf{P\ (t)}} \tag{4}$$

Where TC oil (t) denotes total oil consumption (MTOE) in a particular financial year, and P is the total population of the nation. Normally, when the GIC rises, a country's energy efficacy decreases. At this time, it is important to note that many countries have begun to implement energy-saving programs.

2.4. Index of National Economy Dependence on Oil Import (G4)

The Index of National Economy Dependence on Oil Import ($IEND_{Oil)}$ is defined as follow:

$$\mathbf{G\ _{4_{(t)}}} = \frac{\mathbf{I\ oil\ import\ \ (t)}}{\mathbf{GDP}} \tag{5}$$

Here, $I_{\text{(oil import) (t)}}$ is the oil import (t) of the total imports in (mtoe) of the fiscal year t and similarly gross domestic product (GDP) in US million dollars in the same fiscal year t.

2.5. Oil Price Proxy (G5)

The oil price proxy is defined as the international market oil price monetary value of imported oil which often creates current account deficits in a country.

2.6. Shannon-Wiener Index (G6)

Shannon wiener index is indicating diversity of oil suppliers which is defined as:

$$\mathbf{SWI} = -\sum_{i=1}^{n} \boldsymbol{pi} \ln(\boldsymbol{pi}) \tag{6}$$

The pi in the above equation represents the value of the i-th element of a group (e.g., a share of oil supplied from the i-th source and n is the number of components in the studied group). The negative in verifies a positive Shannon-Wiener index value due to the property of oil logarithms. A low index value indicates a strong requirement for oil in terms of energy supply.

2.7. Herfindahl-Hirschman Index (G7)

The Herfindahl-Hirschman Index (HHI) is the diversity index mostly used to calculate marketplace attention or concentration. It is defined as:

$$\mathbf{HHI = 10{,}000\ (S_1^2+S_2^2+S_3^2+\ldots\ldots. +S_n^2)} \tag{7}$$

Here, Si represents the market share of the i-th element in a group, and n represents the number of elements in the viewed group. The descriptive data of the above indicators are given in Table 1, normalized all the factors according to formula.

$$\mathbf{Z_{n,\,t}} = \frac{G_{n,t} - \min\left(G_{n,T}\right)}{\max\left(G_{n,T}\right) - \min\left(G_{n,T}\right)} \tag{8}$$

The above normalized formula for all selected risk factors on the 0-1 scale. The value 0 is given to the country with lowest value of the selected risk indicator and value of 1 is given to the country with the highest value of the risk indicator. Table 1 consist of a summary of the factors' statistics. For n=1....7, where Zn, t is a normalised factor, and t and T are the corresponding year and total observation period, respectively, 1995-2017.

Table 1: Descriptive Data

	G_1	G_2	G_3	G_4	G_5	G_6	G_7
Maximum	1	1	1	1	1	1	1
Minimum	0	0	0	0	0	0	0
Mean	0.333	0.347	0.379	0.335	0.428	0.334	0.456
Standard Deviation	0.3404	0.365	0.334	0.384	0.328	0.284	0.236
Skewness	0.697	0.619	0.575	0.664	0.460	0.825	0.034
Kurtosis	-1.159	-1.304	-1.136	-1.428	-1.316	-0.543	-0.373
# Of observation	23	23	23	23	23	23	23

The normalized indicators values are used to calculate correlation matrix by Eq. (2.8) between variables. After checking correlation between variables, it shows the importance of indicator then performed PCA methodology to create an index. The PCA methodology consist of taking correlation matrix, eigenvalues, rotated component loading by orthogonal rotation matrix, and lastly, score coefficient. (Pearson, 1901; Ho, 2006). Correlation coefficients are calculated according to formula:

$$\mathbf{r} = \frac{n(\sum xy)-(\sum x)(\sum y)}{\sqrt{[n\sum x^2-(\sum x)^2]-[n\sum y^2-(\sum y)^2]}} \tag{9}$$

Here n shows number of observations, x and y are interdependent variables. The correlation matrix result is given in the Table 2, results indicated that most indicator are important and could further taken for PCA methodology. This table shows the correlation of the S matrix between seven indicators, which is used to derive eigenvalues λ as shown (Table 3) in solving the detrimental term |S- λ I|= 0 for λ, where I is regarded as an identical matrix.

Table 2: Correlation matrix (S)

	G_1	G_2	G_3	G_4	G_5	G_6	G_7
G_1	1						
G_2	0.943***	1					
G_3	0.958***	0.967***	1				
G_4	0.783***	0.799***	0.766***	1			
G_5	-0.917***	-0.965***	-0.948***	-0.789***	1		
G_6	0.4713**	0.388*	0.4545**	0.577**	-0.392*	1	
G_7	-0.286	-0.264	-0.278	-0.464**	0.246	-0.866***	1

Notes: "*", "**", "***" shows statistical significance of 10%, 5%, 1% respectively.

The result of statistical analysis which are shown in Table 2 of interdependent oil risk indicators indicated that Energy structure (G_1) has a strong positive and highly significant correlation with oil intensity (G_2), Gross inland consumption (G_3), index of national economy independence of oil import (G_4), Shannon- Weiner-Index (G_6), strong negative and highly significant correlation with oil price (G_5) moderate negative and significant correlation with Herfindahl-Hirschman Index (G_7).

Oil intensity (G_2) also has a strong positive and significant correlation with Gross inland consumption (G_3), Index of national economy independence of oil import (G_4), strong negative correlation with oil price (G_5) strong positive correlation with Shannon- Weiner-Index (G_6), moderate negative correlation with Herfindahl-Hirschman Index (G_7).

Gross inland consumption (G_3) has strong positive and significant correlation with Index of national economy independence of oil import (G_4) strong negative correlation with oil price (G_5), strong positive correlation with Shannon-Weiner-Index (G_6) weak negative and non-significant correlation with Herfindahl-Hirschman Index (G_7).

On contrary, Index of national economy independence of oil import (G_4), has strong negative and significant correlation with oil price (G_5), strong positive correlation with Shannon-Weiner-Index (G_6), moderate negative and significant correlation with Herfindahl-Hirschman Index (G_7).

Oil price (G_5) has moderate negative and significant correlation with Shannon-Weiner-Index (G_6), weak positive and non- significant correlation with Herfindahl-Hirschman Index (G_7). Shannon-Weiner-Index (G_6) has strong negative correlation with Herfindahl-Hirschman Index (G_7)

Table 3: Eigenvalue of correlation matrix

	λ_1	λ_2	λ_3	λ_4	λ_5	λ_6	λ_7
Eigenvalues	5.45918	1.17636	0.20776	0.08430	0.06086	0.00858	0.00296
Proportion of Variance (%)	77.988	16.805	2.968	1.204	0.869	0.122	0.042
Cumulative Variance (%)	77.98	94.79	97.76	98.96	99.83	99.95	100

The number of eigenvalues is used to decide the number of principal components, first two keep the principal component with largest eigenvalues. Namely Kaiser Criterion, we only use the components have greater than one eigenvalue. The PC1 explain 77.9% of the variance, PC2 explain 99.4% of total variance in correlation.[19]. Therefore, we select only two principal component of rotation component matrix Table: 04. Furthermore Table: 04 is used to calculate the weighs of each indicator calculated as following equation:

$$\beta_m = \frac{C_{mi}\,\lambda_i}{\sum_{n=1}^{7}\lambda_n} \tag{10}$$

Here m is represented numbers of indicator 1…,7 for each indicator, where Cni is the largest value of component Ci, i represent values of components = 1………6, of each row in Table 4.

Table 4: Component rotated matrix (C)

	C_1	C_2
G_1	-0.419	-0.128
G_2	-0.417	-0.149
G_3	-0.405	-0.260
G_4	-0.413	0.001
G_5	0.351	0.399
G_6	-0.348	0.497
G_7	0.269	-0.698

The weights of each indicator are calculated by dividing by the sum of coefficients. Finally, the coefficients derived by equation (10) are applied to analysis the oil supply security index.

$$\text{OSSI} = 0.197G_1 + 0.196\,G_2 + 0.191G_3 + 0.195G_4 + 0.005G_5 + 0.069\,G_6 + 0.097G_7 \tag{11}$$

Where each coefficient the total weight of the index's equivalent normalised indicators throughout the observation period. Therefore the indicator, i.e., the share of oil consumption in primary energy consumption (G1), the share of GDP in the oil consumption (G2), the share of population in the oil consumption (G3), the share of oil import in the GDP (G4), a proxy for oil import prices [15] (G5), and a representation for diversity of import source countries (G6 and G7) with shares of 19.7%, 19.6%, 19.1%, 19.5%, 0.5%, 6.9%, 9.7%, respectively.

3. Results and Discussions

The total weights yearly values of normalized factors have been used to analysis historical OSSI by using Eq. (11). Fig. 3.1 depict that OSSI and the involvement of individual normalized indicators during period from 1995-2017. The historical curve of Pakistan's OSSI can be observed under four different period 1995-1998, 1999- 2005, 2006-2009, 2010-2017, the peak value of OSSI is observed in the period of 1997 and 1998. As shown in the above graph the trend curve of OSSI is first increasing then it goes towards in the second decreasing trend, while the third period the trend curve of OSSI is smooth and then moved towards fluctuating trend. This simply means that openness in Pakistan's energy structure to oil supply firstly faced low oil supply security risk due to high dependency on oil imports increased and oil intensity but at same time oil price hasn't high to show a peak in 1998. Furthermore, flat period, mainly since 2006-2008, through which the OSSI has improved.

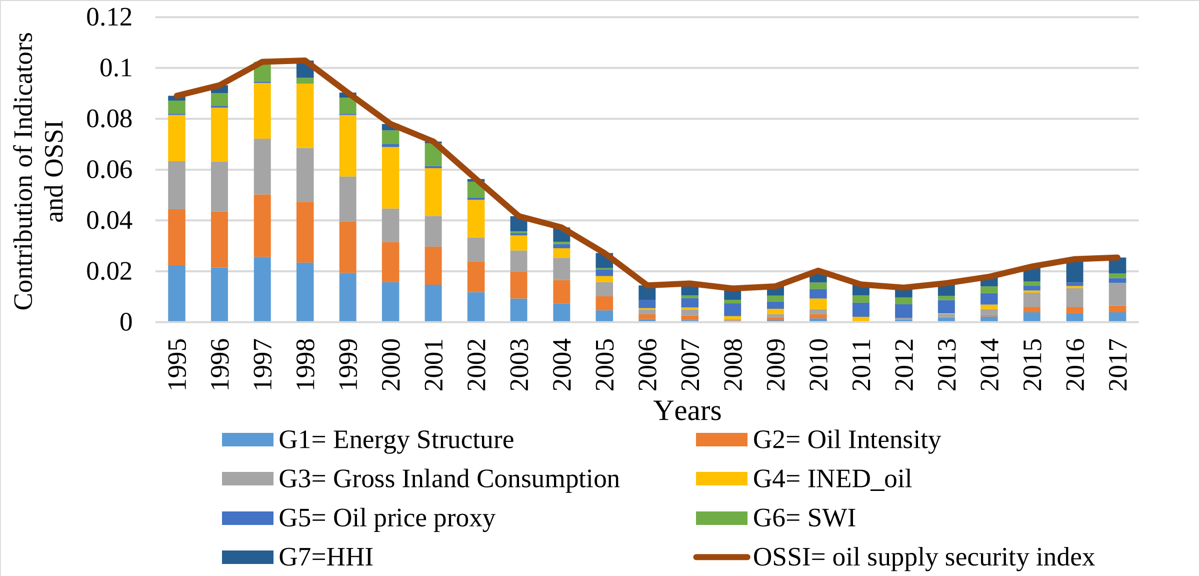

Fig. 1: Oil Supply Security Index (OSSI) of Pakistan, Structure of OSSI and involvement of individual factor, in 1995-2017.

Fig. 1 is obviously showing the yearly involvement every single normalized indicator has significant difference in the arrangement of the OSSI over the complete period. For example, In 1995 G1, G2, G3, G4 high contributed to the OSSI with shares percentage of 25%, 24.8%, 21.2% and 20.1% respectively and relatively low shares of indicator such as G5, G6, and G7 were 0.5%, 5.8%, 2.1% respectively, in 2017, there is variation in value of relative shares of indicators such as G1, G2, G3, and were 15%, 10.7%, 7.5%, 6.89% and 24.6% respectively, where the value of G4 contribution has shown high 35% in this year. In general, the shares of G1, G2, G3, G4 were gradually increasing in the year of 1995-2005 while the value of G5, G6, G7, were fluctuating in these years. Whereas values of G4, G5, G7 indicators contribution in the OSSI were gradually increasing in the year of 2006-2017 and in the same year the value of other indicators contribution G1, G2, G3, G6 are fluctuating throughout the time.
In 1995-1997, shows as first increasing period which is contribution different of indicators, OSSI were commonly dominate by G1, G2, G3, G4, G6, while the effect of G5, G7 were very negligible. While increasing oil consumption leads to G1, G2, G3, G4 to increases over this period, and, oil import diversity, had lowest value due to Pakistan was importing oil from different source of countries, Romania, Italy, Georgia etc. During the same period, unstable international oil price was around 29.8 $ per barrel in 1997 - the contribution oil price (G5) was low. The high values of OSSI indicates that low oil supply security at this period.
In the second following decreasing period 1999-2005, the contribution of G1, G2, G3, G4 indicators was decreasing due to the decreasing in oil consumption and share of alternative energy source gas was used at this time to reduce current account deficit but contribution of (G5) and (G7) indicator were increasing which shows the low values of OSSI that indicates high oil supply security index. In 2005, oil prices rose all around the world due to a drop in oil supply from Iraq, which has significant oil reserves. Additionally, Pakistan experienced an earthquake in 2005, which had a negative influence on all sectors of the economy.
Likewise, in the third stable period between 2006 and 2009, there was less contribution of factor which effect on OSSI graph therefore in OSSI graph is constantly stable due to contribution of indicators G1, G2, G3, G4 was decreased because of G5, G6 and G7 indicators contribution were very high, and these factors restrict to increase involvement of G1, G2, G3, G4. In 2008, there was a global financial crisis, which caused oil prices to rise both nationally and internationally, having a negative influence on the economy.
In the last, during the fourth period fluctuating trend is noticed in 2010-2017, the OSSI has been towards risen growth mostly because of oil prices, oil consumption and import dependency increases along with other indicators contribution also increased which indicated that need oil supply security.

4. Conclusion and Policy Implications

This study analysis oil security uses the PCA approach to create an oil supply security index (OSSI) for Pakistan, considering seven indicators related to Pakistan's history of oil supply from 1997 to 2017. The outcome of different individual indicators for depict of OSSI that (1) the share of oil consumption in primary energy consumption, (2) the share of oil consumption in GDP, (3) the share of oil consumption per capita, (4) the share of oil import in GDP, (5) oil price proxy (6) diversification of oil importers from different countries and with shares of 19.7%, 19.6%, 19.1%, 19.5%, 5.5%, 6.9%, 9.7% respectively.

It is noticed that the OSSI rose rapidly between 1995 and 1998, reaching the highest level in 1997, then declining from 1998 to 2006 after that smooth period 2006 to 2009 then 2010 to 2017 showing fluctuating trend. This means that Pakistan was vulnerable due to oil imports and high oil prices including other indicators has affected oil supply security in different period.

It was also observed that different dynamics had an impact on the OSSI's trend at different periods. Although four parameters, namely the percentage of oil consumption in primary energy, the share of oil consumption in GDP, the share of oil consumption in population, and the share of oil import in GDP, were significant most of the time. OSSI was influenced by other factors at different times. For the time being, while diversification of import sources dominated other factors, the proxy of oil import price became a prevalent characteristic during the 2000s; and it was the period of increasing costs of other commodities followed by the 1997 financial crisis.

On the one hand, the significant policy measure familiar reduces oil supply vulnerability by increasing oil supply diversity in Pakistan, given the fact that the diversity of oil import sources contributes just 6.9 percent to the overall OSSI in Pakistan's situation, would indeed become unjustifiable for oil supply. In Pakistan, however, the percentages share of oil in primary energy consumption and import are the dominating drivers, and the vulnerability will stay high if oil maintains an extensive contributor to the energy mix. As a result, government should think about mass transits system in the country which play an important role reducing oil consumption and creates work opportunities to expand business and government needs to apt its local resources in the energy mix to overcome reliance on imported fuels.

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