Energy Models for Pakistan

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Abstract:

It is of great significance to forecast energy related information in advance for the sake of reducing or avoiding consequent losses while predicting future economic scenario in the country. Long-range Energy Alternatives Planning (LEAP) is an integrated modelling tool that can be used to track energy consumption, production and resource extraction in all sectors of an economy, which has been developed by the Stockholm Environment Institute. LEAP model was used for realistic Integrated Energy Planning (IEP) for Pakistan. Many researchers have used LEAP model for this purpose. We have proved that forecast values produced by this model are not reasonable. Forecast values reveal 10% to 24% relative errors when compared with recent observed values. It is therefore a need to develop a few models which can produce reliable forecasts for near and far future in order to help local energy planners. In this study we developed an exponential model and an Autoregressive Integrated Moving Average (ARIMA) models. ARIMA is a statistical analysis model that uses time series data to either better understand the data set or to predict future trends in the process under study. Models were used to forecast total electricity consumption in Pakistan from 2019 to 2030. A comparison of forecast values from published paper was done. Our predicted values revealed less than 10% relative errors when compared with three observed values.

Keywords: Energy models; LEAP model; exponential model; ARIMA model

1. Introduction:

As a consequence of rapid development of the economy, the total energy consumption of world has been growing. The ratio of electricity generation to whole energy consumption has increased due to the substitution of customary fossil energy. By 2060 the fossil fuel will be depleted [1]. Thus, there is a need to develop integrated energy development plans in every country. France has been studying to produce its 100% energy requirement through renewable energy sources by 2050 [2]. The economic development of Pakistan has been severely restricted due to energy poverty, and power shortages. It is therefore, significant to balance the relationship between power supply and demand. To achieve balance, a prediction of electricity generation and consumption in Pakistan is required. Thus, in this study, a few well-known methods are applied and forecast results are compared.

Researchers used ARIMA models [3-6] and logistic models [7-11] to predict energy demand and consumption in the country. Some authors use LEAP model for this purpose. However, a few users use LEAP incorrectly, or the data they use are unreliable, so they get unrealistic forecast values [12]. LEAP model was used for realistic Integrated Energy

Planning (IEP) for Pakistan [13]. Many researchers have used LEAP model for this purpose [14].

It is important to note that Pakistan lacks reliable data on its energy resources as well do not have dependable long-term energy demand forecasts. Therefore, we need to develop reliable energy forecast models for Pakistan. Pakistan has introduced several reforms to achieve sustainable power development in last two decades [15].

Two key shortcomings pertaining to energy models have been observed in developing countries like Pakistan. Firstly, the models do not effectively make decisions, but rather provide a set of alternatives based on modeling parameters; and secondly, the complexity of these models is often poorly understood by the decision makers [16]. So, simple and effective energy forecast models are the need of our country.

It is better to develop simple and advanced models for countries of our region. As a first step, we are trying to introduce two simple mathematical models, an exponential model and an Autoregressive Integrated Moving Average (ARIMA) model, which is a statistical analysis model that uses time series data to either better understand the data set or to predict future trends in the process under study. Here, we forecast total electricity consumption in Pakistan from 2019 to 2030. We do a comparison of forecast values from published paper ([17]) and our proposed models for total electricity consumption in Pakistan (see Table 2).

2. Methodology:

In general, multiple regression economy model is used as forecast model for a country. Such models use some of the economic indicators, but impact of uncertainty in a country is not included in the model. As a result, the forecast value seems to be for ideal conditions. Consequently, such forecast values are over or under estimated.

For the development of proposed models 10 years' data set (2009 to 2018) was used [17]. Exponential model seems to be the appropriate forecast model. Model parameters values and p-values are given in Table 1. Forecast values for 12 years (2019 - 2030) are given in Table-3. Figure 1 depicts the observed values of total electricity consumption in Pakistan (2009 to 2018) and fitted exponential model.

Exponential Model:

$$f(t) = a e^{bt} \tag{1}$$

we define f(t) as Totcons[t]:= total energy consumption function. After model fitting we obtain the following model.

$$\text{Totcons}[t] = 70.25 e^{0.04t}; \quad t = 1 \text{ for } 2009 \tag{2}$$

Forecast values from exponential and ARIMA(0,1,0) are very close (see Table 3).

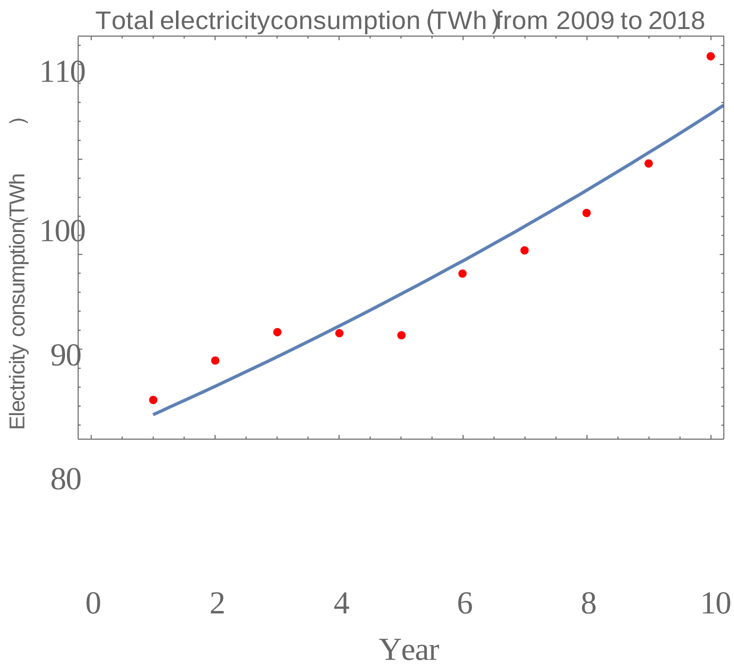

Fig. 1. Observed and simulated exponential energy model for Pakistan.

Table: 1 Model parameters estimates

Parameters	Estimate	Standard Error	t- Statistic	P- Value
a	70.25	1.98	35.38	4.45×10^{-10}
b	0.04	0.0042	9.59	0.000012

Table: 2 Relative errors of Forecasts

Years	[a]Observed values	Forecast from our exponential model	Forecast from published [b]model-1	Forecast from published [c]model-2
2019	106.93	109.12, Rel-er=2.1%	NA	NA
2020	109.46	113.58, Rel-er=3.7%	136.5, Rel-er=24.7%	119.2, Rel-er=8.9%
2021	116.82	118.22 , Rel-er=1.2%	NA	NA

[a]Observed values [18].
[b]model-1: forecasted using LEAP under the baseline scenario.

[c]model-2: forecasted using LEAP under the energy conservation scenario.

Simulation method can also be used for the forecast of energy values [19].

Table: 3 Total electricity consumption (TWh) forecasts (2019 - 2030)

Years	Observed values	Forecast from Exponential model	Forecast from ARIMA(0,1,0)	Forecast from LEAP-BL	Forecast from LEAP-EC
2019	106.93	109.12, Rel-er=2.1%	114.0, er=6.6%	NA	NA
2020	109.46	113.58, Rel-er=3.7%	118.0, er=7.8%	136.5	119.2
2021	116.82	118.22 , Rel-er=1.2%	122.9, er=5.2%	NA	NA
2022		123.04	126.94	168.5	157.5
2023		128.07	130.96	NA	NA
2024		133.30	134.98	208.4	187.9
2025		138.75	139.0	NA	NA
2026		144.41	143.02	258.5	224.5
2027		150.31	147.04	NA	NA
2028		156.45	151.06	320.7	264.9
2029		162.84	155.08	NA	NA
2030		169.50	159.1	399.0	312.6

Linear Model:

Totcons[t]= 69.24 + 3.44 t; t = 1 for 2009

RMSE: 3.36

Linear model was also fitted but its RMSE value was higher than the exponential model. Also linear model is not adequate for long-term forecasting. That is why we preferred exponential model.

Root mean squared error (RMSE) measures the residual errors, which gives a global idea of the difference between the predicted and actual values.

$$RMSE = \sqrt{\frac{\sum_{i=0}^{n} (Ai - Pi)}{n}} \quad (3)$$

Here, A_i and P_i stands for actual and predicted values respectively. Next, we develop time series model for the comparison and contrast of exponential model.

Mathematica 12 was used for the calculations, fitting of models and plotting of graphs in this study [20].

Time Series Modelling of Energy Data:

We test family of Autoregressive Integrated Moving Average (ARIMA) model, which is a statistical analysis model that uses time series data to either better understand the data set or to predict future trends in the process under study.

ARIMA(p,d,q) is a model in which p is the AR order value, d is the number of data differencing processes until the data reaches the stationary condition, and q is the MA order. AR model depends on the value of previous observations. In general, the AR model is as shown in equation (4) below.

$$y_t = \alpha_1 y_{t-1} + \ldots + \alpha_p y_{t-p} + e_t \quad (4)$$

Here,
y : variable value at time t

α_i : AR coefficient; i : 1,2, ..., p

e : error value at time t

p : AR order.

The MA model, in general, is as in equation (5) below.

$$y_t = e_t - \theta_1 e_{t-1} - \cdots - \theta_q e_{t-q} \quad (5)$$

Here,
y : variable value at time t

θ_i : coefficient of moving average ; i : 1,2, ..., q

e : error value at time t

q : MA order

The MA model is influenced by the current error value and the error value with a certain weight in the past [21]. The Akaike Information Critera (AIC) is used for the decision of best fitted model [22].

ARIMA(0,1,0) Model:

The ARIMA (0,1,0) model can be written as:

$$\hat{Y}_t = Y_{t-1} + e + c \quad (6)$$

It is a random walk model with a constant trend. It is called random walk with drift. Table 4 gives the family of ARIMA models tested while searching for the best fitted time series model for Pakistan energy data. Table 5 shows the estimated parameter details. Figure 2 depicts the observed energy values and simulated ARIMA(0,1,0) energy model for Pakistan.

Table: 4 ARIMA models tested to obtain best model

Models	AIC values	Best Model
ARIMA (0,1,0)	**27.9452**	**ARIMA** (0,1,0)
ARIMA (0,1,1)	29.5147	
ARIMA (1,1,0)	29.6727	
ARIMA (0,2,0)	29.8691	
ARIMA (0,2,1)	31.0629	
ARIMA (1,1,1)	31.3609	
ARIMA (1,2,0)	31.3672	
ARIMA (1,2,1)	32.4673	
ARIMA (1,3,1)	34.0848	
ARIMA (0,3,1)	34.8614	

Table: 5 Best **ARIMA** (0,1,0) Model parameters estimates

Parameter	*Coefficient Estimate*	*Standard Error*	*t-Statistic*	*P-Value*
AR 1	1.0004	0.0193	51.81	< 0.001

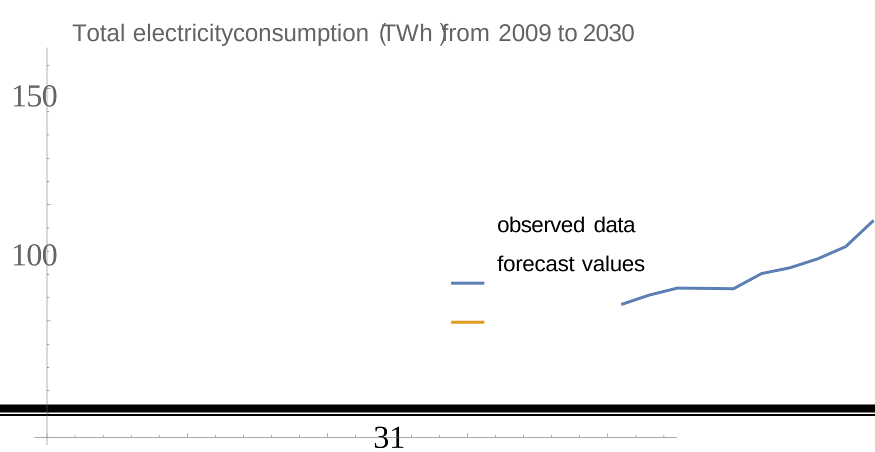

Fig. 2. Observed and simulated ARIMA(0,1,0) energy model for Pakistan.

3. Results and Discussion:

Exponential and ARIMA (0, 1, 0) models were found to be the best models with the smallest error as compared to advanced long range prediction model, LEAP. Exponential model has an average percentage error of 2.3%, whereas ARIMA (0, 1, 0) has an average percentage error of 6.5% based on the prediction results of three observed values. On the other hand, LEAP produced an average percentage error of about 11% based on the same criterion. According to results, the highest accuracy is obtained in the medium term prediction with the exponential model. Based on the time period, ARIMA (0, 1, 0) is the second best model for decisions regarding total energy consumption prediction in Pakistan.

This study aims to help energy planners to make decisions by making medium and long-term predictions using the exponential and Auto-Regressive Integrated Moving Average (ARIMA) methods. In the best order determination experiment, ARIMA (0,1,0) was found to be the best model with the smallest AIC value. Finally, based on the time period, we can say that exponential and ARIMA (0, 1, 0) models are good for short and medium-term energy consumption forecasts.

4. Conclusion:

This study used yearly data for 10 years for the development of energy model of Pakistan. We have shown that exponential and ARIMA models produce better energy forecast values as compared to advanced LEAP model predicted values for Pakistan. Monthly data sets are required for the analysis of seasonal impacts of energy use on different local industrial sectors. Moreover, large reliable data sets will be used for further analysis by developing regression and growth models as being utilized in other countries. Multiple linear regression (MLR) and ANNs are also used to predict the long-term electricity consumption in several countries using some selected economic factors.

Literature survey reveals that while estimating future economic conditions in Pakistan or in any South East Asian countries, the researchers use computer models developed by western scientists, which are in fact for the countries with very low degree of uncertainty and low level of corruptions in the private and public sectors. According to several published papers and Asian Development Bank reports [23-25], corruption is a common phenomenon in South East Asian countries. As for as its impact on country’s economy is concerned it might introduce slight or large forecast errors in the future economic scenario if complicated advanced models are used. In some cases it might result in a total failure in predicting future economic conditions in the country as we have observed in case of Sri Lanka. Exchange rate of US$ in Pakistan is going up with phenomenal speed [26].

Above report also shows that the rate of inflation in Pakistan is at two stages back as compared to Sri Lanka. In June 2022, inflation in Pakistan was 21.3%. Sri Lanka crossed this number in March 2022. It attained its peak value 45.3% in May 2022. Sustainable and serious efforts should be put to develop infrastructure for the use of renewable energy in Pakistan. Our next target is to develop the detailed economic model for Pakistan.

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