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Empirical Modelling of Consumer Price Index of Electricity and Percentage Inflation for Dhofar Governorate in Sultanate of Oman

K.J. Saravanaraj[1*], L. Gerardo[2], S. Sivamani[3]
Engineering Department, University of Technology and Applied Sciences, Salalah
Corresponding Author: K.J. Saravanaraj s.raj@sct.edu.om

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A B S T R A C T

The aim of the present work is to develop a mathematical model relating the electricity consumer price index over the period from January 2013 to March 2022. The data was collected from the Data Portal of National Centre for Statistics and Information, Oman. The electricity consumer price index was constant at 100 from January 2013 to August 2012 and changed from September 2021 to January 2022 and then remained constant, Linear, quadratic, cubic, quartic, quintic, exponential, logarithmic and power models were used to fit the collected data. Based on R^2, the quantic model fitted well with the collected data. The results showed the best goodness of fit between collected and model-predicted values.

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INTRODUCTION

The Sultanate of Oman is a country in southeastern Arabian Peninsula, composed of several topographic features, 82% by desert and valleys, 15% by mountainous ranges, and 3% by coastal areas (Sivamani et al., 2021). The country is administered through 11 governorates, the largest being the Dhofar Governorate with less population density next to Al Wusta. Dhofar is surrounded by desert in the northwest and mountains in the southern part. Apart from Dhofar region, which has a strong monsoon climate and receives warm winds from the Indian Ocean, the climate of Sultanate of Oman is extremely hot and dry most of the year (Hercher & El Kenawy, 2020).

One of the prevalent indicators of any country's progress is commercial and industrial establishments. Many of these entities depend on electricity and transport. It simply means that electricity plays a vital role in the modern life of human (Oyedepo, 2012). As of 2020, Oman's population has the 100% access to electricity. Electricity can be produced by converting mechanical energy into electrical energy through different turbine generator sets (Okonkwo et al., 2021). Consumer price index (CPI) measures the overall change in consumer prices based on a representative basket of goods and services over time. The CPI is the most widely used measure of inflation, closely followed by policymakers, financial markets, businesses, and consumers (Gooding, 2011).

In Oman, there are three sources of energy: natural gas, oil, and renewable energy (Kazem, 2011). As of 2022, electricity production in Oman from renewable energy has reached 650 MW in which the Dhofar Wind Power Plant contributes 50 MW. The rest of the power plants produced electricity through natural gas and oil with a combined capacity of 12,477 MW in which power plants in Dhofar contribute to 1165 MW (Kazem et al., 2011; Umar, 2017; Rajasekar, 2014). In May 2022, electricity production in Oman reached 4,245 GWh as compared with 3,747 GWh in the previous month. The monthly electricity production in Oman is averaging at 2,449 GWh from Jan 2009 to May 2022 (Albadi, 2017; Charabi & Al-Badi, 2015).

In Oman national power grid, there are 95 grid stations including the main interconnected system (MITS) and Dhofar system, with a high-power system availability of 98.972%. The lengths of 400, 220, and 132 kV transmission lines are 1382.75, 1959.89, and 4369.3 km, respectively (Al Riyami et al., 2019). The operating voltage 400, 220, and 132 kV are used for the existing transmission system in the rest of Oman while only 132 kV operating voltage is used for Dhofar region (Marzouk et al., 2019). Muscat Electricity Distribution Company, Mazoon Electricity Company, Majan Electricity Company, and Dhofar Integrated Services Company are the four distribution and supply holders in Oman taking the large amount of power transmitted through the main grid stations to supply the distribution systems. Another seventeen private customers are directly connected to the transmission system at 220 kV or 132 kV lines (Al Habsi et al., 2022).

Regression analysis is a form of predictive modelling technique which investigates the relationship between a dependent (target) and independent variable(s) (predictor). This technique is used for forecasting, time series modelling and finding the causal effect relationship between the variables. Also, it is an important tool for modelling and analysing data (Vijayanand et al., 2021a). In the present study, various models were fir to the data points, in such a manner that the differences between the distances of data points from the curve or line is minimized. There are various kinds of regression techniques available to make predictions. These techniques are mostly driven by three metrics (number of independent variables, type of dependent variables and shape of regression line) (Sivamani & Baskar, 2015).

Linear regression is one of the most widely known modeling technique. It is usually among the first few topics which people pick while learning predictive modeling. In this technique, the dependent variable is continuous, independent variable(s) can be continuous or discrete, and nature of regression line is linear (Vijayanand et al., 2021a). It establishes a relationship between dependent variable (Y) and one or more independent variables (X) using a best fit straight line (also known as regression line). It is represented by an equation

$$Y = a + bX + e$$

where a is intercept, b is slope of the line and e is error term. This equation can be used to predict the value of target variable based on given predictor variable(s). A regression equation is a polynomial regression equation if the power of independent variable is more than 1 (Muthusaravanan et al., 2019). The equation below represents a polynomial equation:

$$Y = a + \sum_{i=1}^{n} b_i X^i + e$$

In this regression technique, the best fit line is not a straight line. It is rather a curve that fits into the data points.

LITERATURE REVIEW

Literature are available to forecast the CPI using multiple regression models. Popescu (2017) built a multiple regression model to explain total CPI from CPI of food commodities, non-food goods and services with a case study from Romania. The model explains the influence of three types of consumption on the evolution of annual index of the total CPI and allows its forecasting. Riofrio et al. (2020) suggest that support vector regression (SVR), long short-term memory (LSTM) neural network, seasonal auto-regressive integrated moving average (SARIMA), exponential smoothing, and Facebook prophet model using a polynomial kernel is the best element to predict the Ecuadorian CPI one year ahead in the future. Finally, the best predictive models and calculated parameters could be used for decision making in several important topics related to social and economic activities.

Gjika et al. (2018) used time series and combined time series-multiple regression models to forecast the CPI in Albania considering the CPI as the dependent variable, and the number of travelers (NT) to Albanian from abroad and the exchange rate (ER) as independent variables. The ER and NT are important for the performance of CPI, and they are positively related to CPI.

Khodamoradi & Saadatmand (2012) used regression model to test the relationship between the CPI and Producers Price Index (PPI) and found out that they are inversely proportional. In addition, the regression model on the growth rate of CPI and the growth rate of the PPI does not have any relationship from each other. They found that SARIMA model is the most appropriate model to forecast the CPI in Ghana based on the data from 2013 to 2018. The CPI forecast values are increasing with a 95% confidence limit.

From the analysis of literature, limited literature has been found from Oman. Hence, the present work aims to develop a mathematical model relating the electricity consumer price index over the period from January 2013 to March 2022.

METHODOLOGY

Data Collection

The electricity consumer price index data with base year as 2012 and percentage inflation from Jan 2013 to March 2022 for Dhofar Governorate was collected from the Data Portal of National Centre for Statistics & Information (NCSI), Sultanate of Oman (https://data.gov.om/). The Data portal is a free and data-sharing portal where anyone can access data relating to the Sultanate of Oman. The Data Portal provides many datasets from different entities, for everyone - citizen, investor, researcher, or developer. The electricity consumer price index was selected due to the change in inflation between 2021 and 2022 in the Sultanate.

Data Analysis

The common univariate empirical models involving multiple coefficients are linear, polynomial (quadratic, cubic, quartic, and quintic), and non-polynomial (exponential, logarithmic and power) as shown in Table 1. Linear, quadratic, cubic, quartic, and quintic models are first-, second-, third-, fourth- and fifth-order forms of polynomial equations. Polynomial models can be used without any limitations (Smith & De Micheli, 1999). However, exponential, logarithmic and power models are non-linear. So, their linear forms, used to evaluate the coefficients, are also provided in Table 1. Non-linear equations are used with limitations. For example, logarithmic and power models cannot be used for negative and zero values in either independent or dependent variables. Likewise, exponential models cannot be used when corresponding independent and dependent variables are zero. So, linear, quadratic, cubic, quartic, quintic, exponential, logarithmic and power models were selected in the present study (Bazeia et al., 2017).

Table 1. Univariate Empirical Models Involving Multiple Coefficients

S. No.	Category	Type of model	Non-linear form	Linear form
1.	Linear	Linear	$Y = A+B.X$	-
2.	Polynomial	Quadratic	$Y = A+B.X+C.X^2$	-
3.		Cubic	$Y=A+B.X+C.X^2+D.X^3$	-
4.	Non-linear	Exponential	$Y = A.e^{B.X}$	$\ln Y = \ln A + B.X$
5.		Logarithmic	$Y = A + \ln X^B$	$Y = A + B.(\ln x)$
6.		Power	$Y = A.X^B$	$\ln Y = \ln A + B.(\ln x)$

Mathematical modelling was performed in Microsoft Excel 2019. Model testing was performed by fitting the collected data to the univariate models. The goodness of fit of the model was evaluated by the coefficient of determination (R^2). In statistics, R^2 is the measure of fitness of empirical models to the experimental or observed data (Chandrasekaran & Sivamani, 2015). R^2 is calculated by using the following Equation (1):

$$R^2 = 1 - \frac{SSE}{SST} \quad (1)$$

where SSE and SST are sum of squares of error and total sum of squares, respectively. In general, R^2 values vary from 0 to 1. Sometimes, models exhibit negative values for R^2, which indicate that the data are not in agreement with the models. R^2 value of zero means that none of the variation in dependent variables corresponds to independent variables. The value of 1 means that variation in dependent variables corresponds to independent variables. For example, the value between 0 and 1 of 0.92 means that 92% variation of dependent variables corresponds to independent variables (Vijayanand et al., 2021b).

The tested model was validated by performing experiments within the range of independent variables to obtain dependent variables because the model is applicable only for the range of predictor variables. If the experimental value fits well with the predicted value, the model is validated (Maran, 2015). From the model validation, suitable univariate models are selected based on $R^2>0.81$ and proceeded for implementation, noting that the final models are validated for the problem.

RESULTS AND DISCUSSION

Figure 1 shows the electricity consumer price index with base year as 2012 and percentage inflation against month and year. Based on the collected data, the electricity consumer index for the month of January 2013 to August 2021 was constant at 100, then a gradual increase for September, October, November, and December at 104.2, 113.3, 114.3 and 117.2, respectively. Beginning the year 2022, there is a decrease of the electricity consumer index for Dhofar and its constant at 115.7.

Similarly, the percentage inflation for the month of January 2013 to August 2021 was constant at zero, then a gradual increase for September, October, November, and December at 4.19, 11.27, 14.26 and 17.15, respectively. Beginning the year 2022, there is a decrease of the electricity consumer index for Dhofar and its constant at 15.71. The change in inflation between September 2021 and January 2022 was observed due to post effects of COVID19.

The relation between electricity consumer price index and percentage inflation is mathematically related as given in Equation (2):

Electricity consumer price index = Percentage inflation + 100 (2)

The electricity consumer price index of 100 is based upon the index average for the period from 2012 through 2021 (inclusive), which was set to 100. So, the consumer price index of 100 means that inflation is back to the level that it was in August 2021, while readings from September 2021 to January 2022 indicate a rise in the inflation level.

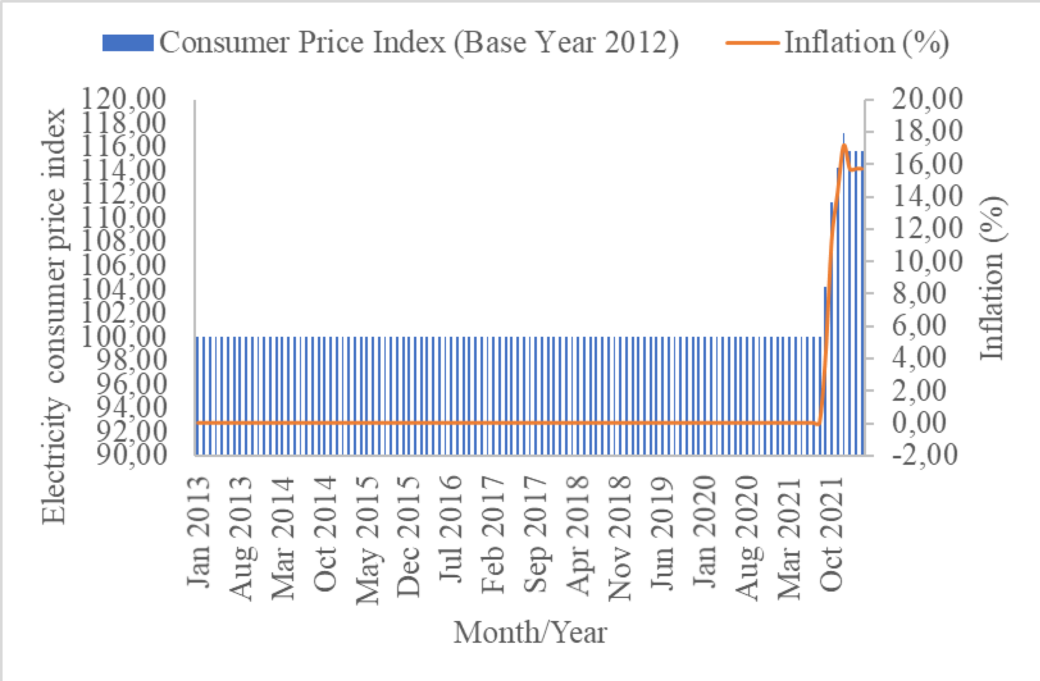

Figure 1. Electricity Consumer Price Index with Base Year as 2012 and Percentage Inflation Versus Month and Year

The collected data was fitted to the below models as given in the Equations (3)-(8),

Linear: $CPI_t = CPI_0 + kD$ (3)

Quadratic: $CPI_t = CPI_0 + k_1D + k_2D^2$ (4)

Cubic: $CPI_t = CPI_0 + k_1'D + k_2'D^2 + k_3'D^3$ (5)

Quartic: $CPI_t = CPI_0 + k_1''D + k_2''D^2 + k_3''D^3 + k_4''D^4$ (6)

Quintic: $CPI_t = CPI_0 + k_1'''D + k_2'''D^2 + k_3'''D^3 + k_4'''D^4 + k_5'''D^5$ (7)

Exponential: $CPI_t = CPI_0\, e^{k'D}$ (8)

Logarithmic: $CPI_t = CPI_0 + \ln D^{k''}$ (9)

Power: $CPI_t = CPI_0.D^{k'''}$ (10)

where CPI is electricity consumer price index, D is value of month and year, and the terms involving k are constants. An appropriate model is selected based on $R^2>0.81$. The fitted models for electricity consumer price index for Dhofar Governorate were shown in Table 2.

Table 2. Tested Models for Observed Data of Electricity Consumer Price Index

Model	Electricity Consumer Price Index	R^2
Linear	$Y=0.0433X+98.421$	0.1639
Quadratic	$Y = 0.0017X^2-0.1515X+102.09$	0.3809
Cubic	$Y = 0.00006X^3-0.0085X^2+0.3098X+97.689$	0.5922
Quartic	$Y = 0.000002X^4-0.0004X^3+0.223X^2-0.465X+102.2$	0.7529
Quintic	$Y = 0.00000005X^5-0.00001X^4+0.0011X^3-0.0392X^2+0.5375X+98.225$	0.8462
Exponential	$Y = 98.538e^{0.0004X}$	0.1661
Logarithmic	$Y = 97.365 + \ln X^{0.9315}$	0.0636
Power	$Y = 97.572\ X^{0.0087}$	0.0644

The model fitting was performed based on Pearson's correlation coefficient of more than 90%, i.e., 0.9. Therefore, a model with determination coefficient of more than 0.81 was found to be suitable to fit the data. Hence, quintic empirical model was found to fit the electricity consumer price index data for Dhofar Governorate.

CONCLUSION AND RECOMMENDATIONS

This work aimed to develop a mathematical model relating the electricity consumer price index over the period from January 2013 to March 2022. The data was collected from the Data Portal of National Centre for Statistics and Information, Oman. The electricity consumer price index was constant at 100 from January 2013 to August 2012 and changed from September 2021 to January 2022 and then remained constant, Linear, quadratic, cubic, quartic, quintic, exponential, logarithmic and power models were used to fit the collected data. Based on R^2, the quantic model fitted well with the collected data. The results showed the best goodness of fit between collected and model-predicted values.

ADVANCED RESEARCH

The present study is limited to the CPI of electricity and percentage inflation data from the Dhofar Governorate during January 2013 to March 2022 with base year as 2012.

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