

Forecasting the Consumption for Electricity in Taiwan

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ABSTRACT

This paper use linear regression and non-linear artificial neural network (ANN) model to analyze how the four economic factors: national income (NI), population (POP), gross of domestic production (GDP), and consumer price index (CPI), affect Taiwan's electricity consumption, furthermore, develop an economic forecasting model. Both models agree with that POP and NI are of the most influence on electricity consumption, whereas GDP of the least. Then, we compare the out-of-sample forecasting capabilities of the two models. The comparing result indicates that the linear model is obviously of higher bias value than that of ANN model, and of weaker ability of forecasting capability on peaks or bottoms. This probably results from: 1) linear regression model is built on the logarithm function of electricity consumption, and ANN is built on the original data; 2) ANN model is capable of catching sophisticated non-linear integrating effects. Consequently, ANN model is the more appropriate between the two to be applied to building an economic forecasting model of Taiwan's electricity consumption.

Keywords: electricity consumption, artificial neural network, linear regression

1. INTRODUCTION

Modeling electrical demand and energy consumption is usually based on historical consumption and the relationship of this consumption to other relevant variables, such as: economic, demographic, climatic, energy price, etc. Multivariate modeling along with cointegration techniques or regression analysis were used in a number of studies on different countries [1-7] to investigate the influence of different determinants on energy consumption. Recently, some studies address to compare forecasting performance for energy consumption using different models on different countries [8-10]. Variables affecting demand and energy consumption may vary from one region to another. A model developed for one region may not be appropriate for another region. Electrical consumption models are required for a variety of utility activities. Therefore, model should be developed for different region for efficient planning and organization.

Taiwan's energy consumption rises sharply from 52.01 million kiloliters of oil in 1990 to 103.42 million kiloliters of oil in 2003 because of rapid economy growth and higher living standard. Among the energy forms consumed, petroleum took up 44.2% in 1990 to 39% in 2003; coal 12.8% to 10.7%; natural gas & liquid natural gas 3% to 2.3%, and electricity 40% to 48%. Electricity consumption takes up almost 50% of the total final energy consumption in 2003. The main object of this study is to analyze and discuss Taiwan's electricity consumption. We focus on the effect brought by four economic factors: NI, POP, GDP, and CPI, on electricity consumption (ELEC) for Taiwan. Moreover, to build a linear and a non-linear economy forecasting models which could be useful to relating government authorities for controlling electrical energy supply.

The rest of this paper is organized as follows: section 2 records the results of data analysis and review. Section 3 presents the empirical results and comparing results of linear and nonlinear models, whereas the last section briefs our findings and concludes.

2. DATA ANALYSIS

The data applied here are 156 monthly data recorded January 1990 through December 2002. The first 132 data recorded 1990 through 2000 are studied to build the forecasting model, while the last 24 data recorded 2001 through 2002 are applied to testify the model. ELEC and the four economic factors: NI, POP, GDP, and CPI, are collected from AREMOS database supervised by the Education Ministry Taiwan. The factor NI has rather high linear relativity with POP (0.99) and CPI (0.97), while POP reacts the same to CPI (0.96). The scatter plot of ELEC to four economic factors exhibit logarithmic trend. So, Log (ELEC) is considered dependent variable in this research. Fig. 1 shows the electricity consumed annually from 1990 to 2002. The consumption gradually increases to hit the peak in summertime, and decreases to the bottom in wintertime.

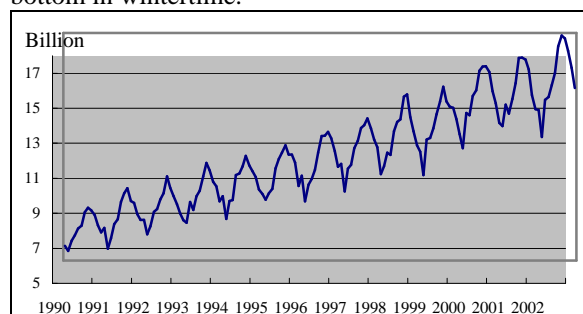


Fig. 1 Electricity consumption in Taiwan

3. EMPIRICAL RESULTS

The following five linear and one nonlinear models are used to find how POP, NI, GDP, and CPI affect Taiwan's electricity consumption, furthermore to build a forecasting model for the issue.

3.1 Multiple linear regression models

This section analyzes and discusses the effect that the four economic factors have on electricity consumption with linear regression model, and develops an economic forecasting model. Because of the linear relationships between logarithm function of electricity consumption and economic factors, this paper use the Log (ELEC) as dependent variable. Taking multicollinearity into account, the experimental formulas are extracted after deleting NI and CPI variables selected by the models with statistics of Mallows C(p) [11], Adj-R², and VIF.

$$\text{Model 1: } LELEC_t = a_1 + b_1 TEMP_t + c_1 GDP_t + e_{1t}$$

$$\text{Model 2: } LELEC_t = a_2 + b_2 TEMP_t + c_2 CPI_t + e_{2t}$$

$$\text{Model 3: } LELEC_t = a_3 + b_3 TEMP_t + c_3 POP_t + e_{3t}$$

$$\text{Model 4: } LELEC_t = a_4 + b_4 TEMP_t + c_4 NI_t + e_{4t}$$

$$\text{Model 5: } LELEC_t = a_5 + b_5 TEMP_t + c_5 NI_t + d_5 GDP_t + e_{5t}$$

where $LELEC = \text{Log (ELEC)}$.

Model 1- 4 present how the four economic factors affect electricity consumption under controlled the temperature,

respectively. Table 1 indicates that POP and NI affect Taiwan's electricity consumption the most reaching 95.18% and 95.17% respectively followed by CPI (92.48%), while GDP the least (59.25%). The normality test for residuals of each model is recorded in Table 1. Though GDP and CPI are both significant indicators to a country's economy, they don't affect Taiwan's electricity consumption as much as the others. This could result from Taiwan government's enforcement on electricity saving and economizing policy.

Model 5, the best economic forecasting model for electricity consumption, is formulated after deleting NI and CPI variables selected by the statistics of Mallows C(p), Adj-R², and VIF. The procedure is practiced to prevent multicollinearity. Compared with model 4, model 5 shows that GDP has significant effect on Taiwan's electricity consumption, but it only surpasses model 4 by 0.34 (=0.9551 - 0.9517). The last row in Table 1 present the estimated coefficient values of standardized regression model. It shows the most crucial factors affecting Taiwan's electricity consumption, according to priority, are NI (0.803), TEMP (0.381), and GDP (0.082). The result agrees with those of model 1 to 4. The Adj-R² of model 5 reaches 0.9551, and passes the normality test for residuals ($p\text{-val}=0.1438$). Below is the formula of model 5:

$$LELEC = 14.639 + 0.024 TEMP + 1.47 \times 10^{-6} NI + 5.44 \times 10^{-8} GDP$$

Table 1 Coefficients using regression and standardized regression

		Intercept	TEMP	GDP	CPI	M	NI	Adj-R ²	Normality ($p\text{-val}$)	Size
Model 1	Estimate	14.462* (120.71)	0.028* (7.77)	4.07E-7* (10.92)				0.5925	0.0060	132
	Standardized	0	0.434	0.610						
Model 2	Estimate	13.134* (176.36)	0.022* (14.42)		0.027* (34.88)			0.9248	0.3100	132
	Standardized	0	0.349		0.845					
Model 3	Estimate	8.019* (47.27)	0.023* (18.29)			3.59E-4* (44.38)		0.9518	0.0379	132
	Standardized	0	0.355			0.860				
Model 4	Estimate	14.726* (466.41)	0.024* (19.69)				1.57E-6* (44.33)	0.9517	0.0197	132
	Standardized	0	0.381				0.857			
Model 5	Estimate	14.639* (364.79)	0.024* (20.45)	5.44E-8* (3.30)			1.47E-6* (32.30)	0.9551	0.1438	132
	Standardized	0	0.381	0.082			0.803			

* Indicates statistical significance at the 0.05 level.

t statistics are in the parentheses.

The model residuals are amplified by exponential transformation because we are fitting the regression model to transformed data (Log (ELEC)) and then must convert prediction for logarithmic back to untransformed units. So, we build a non-linear ANN model on the original value of electricity consumption.

3.2 ANN models

The artificial neural network (ANN) consists of an input layer, an output layer and one or more intervening layers also referred to as hidden layers. Each layer consists of multiple neurons that are connected to neurons in adjacent layers. The connection weights and node biases are the model parameters.

To use an ANN model for forecasting, forecasters must first build it. The model building process is called the network training or learning. Usually, in applications of ANNs, total available data are split into a training set and a test set. The training set is used to build the network model and then the forecasting ability of the network is evaluated from the test set. In this paper, the 132 monthly data recorded 1990 through 2000 are training samples, while the 24 monthly data recorded 2001 through 2002 are testing samples. POP, NI, GDP, CPI, and TEMP are the network input values, and electricity consumption is network output value. More than 60 experiments are performed to determine the best combination of the learning rate, momentum, number of hidden layers, number of hidden nodes, learning rule, and transfer

$$S_i = \frac{\partial \hat{Y}}{\partial X_i} = \sum_{t=1}^h \frac{\partial \hat{Y}}{\partial NET_t} \frac{\partial NET_t}{\partial Z_t} \frac{\partial Z_t}{\partial NET_t} \frac{\partial NET_t}{\partial X_i} = \sum_{t=1}^h [f'(NET_t) v_t f'(NET_t) w_{it}] \quad (1)$$

The absolute sensitivity value of each input variable represents its relative effect with electricity consumption. Crucial factors affecting electricity consumption are, by priority, NI, POP, TEMP, CPI and GDP, and their absolute sensitivities are 15.142, 7.696, 3.068, 2.344 and 0.989 (see Table 2). The result agrees with that of regression model on which the economy indicators, GDP and CPI, are not the key factors to Taiwan's electricity consumption, but POP and NI.

Table 2 The sensitivities of electricity consumption to five economic factors

	TEMP	GDP	CPI	POP	NI
Sensitivity	3.068	0.989	-2.344	7.696	15.142

Once the two models to predict monthly electricity consumption are developed, we empirically examine the relative effectiveness of the models in predicting electricity consumption using the data from January 2001 to December 2002.

3.3 Out-of-sample forecasting performance results

We use three statistics: RMSE, MAE, MAPE, and scatter diagram to see the out-of-sample ability of the linear and the non-linear models. Table 3 shows the three statistic values fall sharply from 1509559.37, 1342149.39, and 8.60% of linear model to 635378.69, 460738.5, and 3.29% of ANN model. It is because of: 1) the dependent variable of regression model is the logarithm value of electric consumption, while the artificial neural network model trains the original value of electricity consumption; 2) the ANN is capable of catching sophisticated non-linear integrating effect. Fig. 6 presents the forecasting values of two forecasting models and ELEC actual value. It clearly shows that the ANN forecast value is closer to the ELEC actual value, and regression model is weaker on foretelling peaks and bottoms. This result proves that the ANN is more appropriate to be applied to build an economic forecasting model for Taiwan's electricity consumption.

function to utilize.

Throughout the training, the NeuralWare utility, 'SAVEBEST' is used to monitor and save the lowest root mean square (RMS) error value from the testing set. The best RMS error result is obtained using a learning rate of 0.2, a momentum of 0.1, and 6 neurons in a single hidden layer that use the generalized delta learning rule and a sigmoid transfer function. The architecture of the best network contains 5 input layer neurons, 6 hidden neurons, and 1 output layer neuron (5:6:1 architecture). The estimations of connection weights w_{it} and v_t are obtained, then apply them to formula (1) to calculate the sensitivities \hat{S}_i (Hwang, Choi, Oh, & Marks [12]).

Table 3 Comparing forecasting measurement errors

	RMSE	MAE	MAPE
Regression	1509559.37	1342149.39	8.60%
ANN	635378.69	460738.50	3.19%

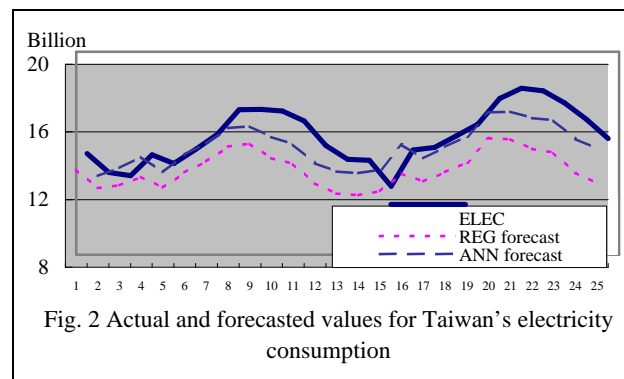


Fig. 2 Actual and forecasted values for Taiwan's electricity consumption

4. CONCLUSION

By adopting linear regression and non-linear ANN models, surprisingly, we find that economy indicators, GDP and CPI, have less effect on Taiwan's electricity consumption than POP and NI. By ANN model, we obtain the crucial factors are, by priority, NI, POP, TEMP, CPI and GDP. Three factors: NI, TEMP, GDP are contained in the best linear economic forecasting model, after excluding the multicollinearity among five factors. By comparing three statistics values: RMSE, MAE, MAPE, and scatter diagram for out-of-sample of two models, ANN's forecasting capability is higher than that of the regression model, and regression model is weaker on foretelling peaks and bottoms. To sum up, the artificial neural network model is more appropriate between the two to help us build the economy-forecasting model of Taiwan's electricity consumption. Furthermore, it is possible to use linear and nonlinear hybrid model and univariate time series to forecast electricity consumption in Taiwan.

ACKNOWLEDGEMENT

This research was supported in part by the National Science Council under Grant NSC 92-2422-H-009-0300 in Taiwan, China.

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