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Modelling Sector-wise Electricity Demand in Sri Lanka: An Application of Vector Autoregressive Model

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Authors' contributions

This work was carried out in collaboration between both authors. Author KANKK designed the study, performed the statistical analysis, wrote the protocol and drafted of the manuscript. Author KV managed the data collection and literature searches. Both authors read and approved the final manuscript.

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Short Research Article

Abstract

The knowledge about the current and future electricity demands is necessary and much useful in planning and decision making for giving proper electricity supply. This study aimed to identify the pattern and to model the sector-wise electricity demand. Sector-wise (domestic, industrial and commercial) electricity demands from 1970 to 2015, were collected from central bank annual reports. The series of second order differences of demand in each sector, which showed stationarity, was modelled by using Vector Autoregressive (VAR) models.

VAR model of order 3 (VAR(3)) could explain the behaviour of series of second order differences. This model showed 85% of minimum accuracy in prediction. There could be seen an increasing trend of demand in all the sectors. Up to late part of 80's, a linear trend could be observed in each sector. Demands in domestic and commercial sectors were almost the same up to around 1988. After year 1988, the demand in domestic sector was higher than the demand in commercial sector. Up to about 2000, demand from industrial sector was higher than the other two sectors. During the period from 2000 to 2006, demand of domestic and industrial were almost the same. But after 2006, demand in domestic sector has gone up than the demand in industrial sector.

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1 Introduction

Among the many energy sources, electricity plays a major role in Sri Lanka. Several institutes such as Ceylon Electricity Board (CEB), Lanka Electricity Company (pvt) limited (LECO), are supplying the electricity. For the generation of electricity, several sources such as thermal power, hydro power, and other non-conventional renewable energy (biomass, solar, wind, tidal, biofuel, ocean wave) are used. Electricity is mostly generated by using the hydro power. Both advantages and disadvantages are associated with these sources in terms of aspects such as initial cost, maintenance cost, space, etc.

Demand for electricity change with time based on some other factors like population growth, development in industrial, commercial and social sectors. For a better electricity supply, advance knowledge on future electricity demand is much important. Forecasting process helps to obtain necessary information in advance by making planning and decision making easy. David [1] has stated that "Forecasts are educated assumptions about future trends and events". According to Demir and Ozsoy [2], forecasting is a complicated process as the factors such as technological innovation, cultural changes, changing social values, unstable economic conditions, new product, stronger competitors, improved services, etc. According to Dahl [3], the demand for energy and products related to energy is studied more than any other factor. There are different models for forecasting and their accuracies are depending on the situations and data considered.

Jayatissa [4] has modelled electricity demand in both domestic and industrial sectors separately by using several models based on ordinary least squares method. He has collected data of 178 house hold consumers from January 1993 to December 1993 for short run analysis and monthly data from February 1980 to October 1993 for long run analysis of electricity demand in domestic sector. It has been found that demand in domestic sector is neither income nor price elastic in both short and long run. For the analysis of demand in industrial sector, he has used annual data from 1971 to 1992 and found that demand in industrial sector is neither output nor price elastic in the short or long run.

Ruwanthi and Wickremasinghe [5] have modelled the sector wise electricity demand in Sri Lanka by using multivariate regression approaches. As the responses, log form of demand has been used while log forms of price of electricity, price of kerosene and income level of consumers have been used as the exploratory factors. Morimoto and Hope [6] have modelled the relationship between electricity supply and GDP by using Granger causality analysis with the purpose of identifying impact of electricity supply on economic growth in Sri Lanka. According to this analysis, change in electricity supply affects changes in GDP.

Amarawickrama and Hunt [7] have studied electricity demand in Sri Lanka by using annual data over the period 1970-2003. Per capita electricity demand has been modelled by using per capita gross domestic product (GDP), real electricity price, and underlying energy demand trend (UEDT). Log form of all these variables have been used in the models. They have tested five cointegration methods which are used in econometric, namely Static Engle and Granger method (Static EG), Dynamic Engle and Granger method (Dynamic EG), fully modified ordinary least squares method (FMOLS), Pesaran, Shin and Smith method (PSS), Johansen method, and structural time series method (STSM). It has been found that underline demand trend varies between the different techniques ranging from negative values to positive values. Further, it has been stated that there is a wide range in the long-run price and income elasticities with the estimated long-run income elasticity (ranging from 1.0 to 2.0) and the long run price elasticity (from 0 to –0.06).

Fatai, Oxley and Scrimgeour [8], has modelled the demand for electricity in New Zealand, by using Engle-Granger's error correction model (ECM), and the autoregressive distributed lag regression approaches (ARDL). Abraham and Nath [9] have compared the performances of neuro-fuzzy approach (an evolving fuzzy neural network and artificial neural network) and Box-Jenkins autoregressive integrated moving average (ARIMA) approach in modeling electricity demand in the state of Victoria, Australia. Monthly electricity consumption in Pakistan has been analyzed by Yasmeen and Sharif [10], by using both linear and nonlinear modeling techniques including ARIMA, Seasonal ARIMA (SARIMA) and autoregressive conditional heteroscedastic (ARCH) and generalized autoregressive conditional heteroscedasticity (GARCH) models.

Jorgensen and Joutz [11] have analyzed the demand for residential electricity of the U.S. mountain region to see how electricity prices and weather conditions affect electricity consumption and greenhouse gas emission. Electricity demand has been modelled by using price of electricity, personal income, number of households, price of natural gas and weather. Weather is a function of heating and cooling days. Conditional vector equilibrium correction model and VAR models have been used for modeling the demand.

Electricity demand in Sri Lanka is mainly dependent on three sectors namely commercial, industrial and domestic. Analyzing sector wise demand separately is not advisable because these components tend to be correlated each other. Even though, there is a possibility to analyze the total demand, it also will lose some important information. Therefore, in this study, sector wise electricity demands were modelled together by taking their inter correlation structure into consideration. A multivariate technique called Vector Auto Regressive (VAR) model was used for modelling these sector-wise demands.

2 Methodology

Sector-wise (domestic, commercial and industrial) electricity demand (in GWh) from 1970 to 2015 were collected from central bank annual reports. For the purposes of model fitting, data from 1970 to 2010 were used, while the data from 2011 to 2015 were used for testing the accuracy of forecast of the fitted model. Correlations of electricity demands among these three sectors were analysed first. They were highly positively correlated each other. Therefore, following VAR model of order p, which consists of 3 endogenous variables $y_t = (y_{1t}, y_{2t}, y_{3t})$ where y_{1t} : demand in domestic sector at time t, y_{2t} : demand in commercial sector at time t, y_{3t} : demand in industrial sector at time t,

$$y_t = A_1 y_{t-1} + A_2 y_{t-2} + ..., + A_p y_{t-p} + u_t ,$$

was used to model electricity demand from each sector. Here, A_i are (3*3) coefficient matrices for $i = 1, 2, ..., p$ and u_t is a white noise.

Stationarity of each series of electricity demand was checked by using graphical methods (time series plot, auto correlation function (ACF), and partial auto correlation function (PACF)) and Augmented-Dickey Fuller unit root test (ADF) with the hypothesis:

H_0: Series need to be differenced to make it stationary vs H_1: Series is stationary.

Since, graphs and ADF test indicated that all the series were not stationary, each series was made stationary by taking differences of demands in adjacent years. The series of second order differences of demand in each sector was stationary. Then, order of the VAR model was selected by using four criterias: Akaike Information criteria (AIC); Hannan-Quinn information criterion (HQC); Schwarz information criterion (SIC); and forecast prediction error (FPE). AIC and FPE proposed order 3 while HQC and SC proposed order 1. According to the orders suggested by those criterias, VAR models of order 1 (VAR(1)) and order 3 (VAR (3)) were fitted. Based on the validity of the assumptions and forecasting performances, model VAR(3) was selected as the best model.

Normality of the residuals was tested with the null hypothesis that residuals are normally distributed against the alternative hypothesis that residuals are not normally distributed, by using Jarque-Bera (JB) normality test. Assumption of constant variance of residuals was tested by using multivariate ARCH test with the null hypothesis of constant variance. Portmanteau test and the Breusch-Godfrey LM (BG LM) tests were used for testing serial correlation of residuals. In that the null hypothesis was that residuals are not serially correlated. Stability of the fitted model was tested by using ACF and PACF of squared residuals.

3 Results and Discussion

The plots of series of electricity demand in each sector are given in Fig. 1. It clearly shows how the demand in each sector varies with time. There can be seen an increasing trend of demand in each sector. Up to late part of 80's (1988) a linear trend can be observed in each sector. Demands in domestic and commercial sectors were almost the same up to around 1988.

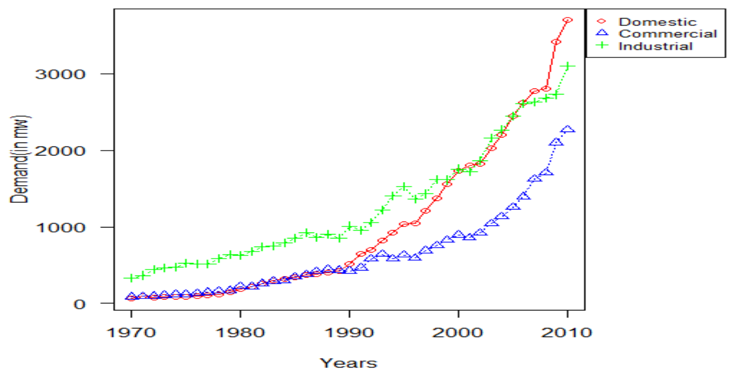


Fig. 1. Plot of series of demand in each sector

During the period from 1970 to 1988, demand in domestic sector has gone up from 62 GWh to 405 GWh with an average rate of 19 Gwh per year, while the demand in commercial sector has increased from 87 GWh to 443 Gwh with a rate similar to domestic sector. Demand in industrial sector has changed from 332 GWh to 905 GWh with a rate of 31 GWh per year. During the period from 1889 to 2010, the demand in domestic sector was higher than the demand in commercial sector and it has reached up to 3696 GWh and demand in commercial sector has exceeded 2260 GWh. Up to about 2000, demand in industrial sector was higher than the other two sectors. During the period from 2000 to 2006, demands in domestic and industrial sectors were almost the same. But after 2006, demand in domestic sector has gone up than the demand in industrial sector. By 2015, demands in sectors domestic, commercial and industrial have exceeded 4500 GWh, 3170 GWh, and 3870 GWh respectively.

Figures in Table 1, explain the correlations structures of demands among these three sectors. Between each pair of sector, a strong positive correlation can be seen. Ruwanthi and Wickremasinghe [5] also have recorded positive strong correlations for pairs of these sectors.

Table 1. Correlation structure among three sectors

	Domestic	**Commercial**	**Industrial**
Domestic	1	0.9855918	0.9884421
Commercial	0.9855918	1	0.9724111
Industrial	0.9884421	0.9724111	1

Results of the ADF test for stationarity of series of second order differences of demand are given in Table 2. *P*-values of ADF test for each series are lesser than the significance level of 0.05 assumed. This implies that series of second order differences are stationary.

Table 2. Results of ADF test

Variable	Test value	*P*-value
Domestic	-4.7465	<0.01
Commercial	-4.9141	<0.01
Industrial	-5.7451	<0.01

Coefficients of the fitted VAR(3) model for the series of second order differences, are given in Table 3 below.

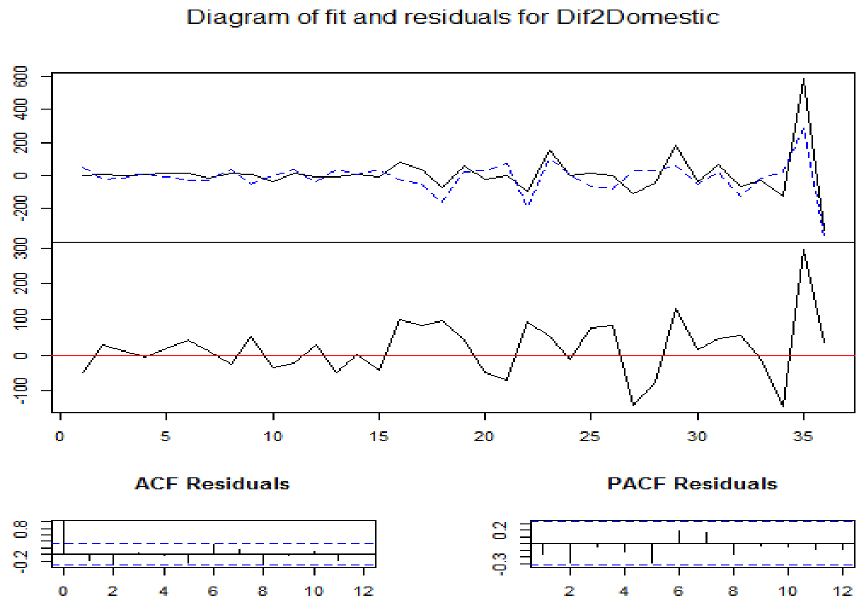
Table 3. Coefficients of fitted VAR(3) model

Independent variable	Dependent variables		
	Dif2Domestic	Dif2Commercial	Dif2Industrial
Dif2Domestic.l1	-0.5662	-0.1223	0.1139
	(0.0408*)	(0.5366)	(0.6932)
Dif2Commercial.l1	-0.2747	-0.6824	0.2891
	(0.4569)	(0.0176*)	(0.4701)
Dif2Industrial.l1	-0.0106	-0.1116	-0.8760
	(0.9492)	(0.3723)	(4.31E-05*)
Dif2Domestic.l2	-0.7120	0.0930	-0.4671
	(0.0833)	(0.7538)	(0.2862)
Dif2Commercial.l2	0.6522	-0.2320	0.4262
	(0.1038)	(0.4262)	(0.3192)
Dif2Industrial.l2	-0.2295	-0.2182	-0.5058
	(0.2965)	(0.1837)	(0.0395*)
Dif2Domestic.l3	-0.9186	-0.3791	-0.4315
	(0.0200*)	(0.1801)	(0.2936)
Dif2Commercial.l3	0.6591	0.0746	1.0626
	(0.0888)	(0.7895)	(0.0141*)
Dif2Industrial.l3	0.0797	-0.0847	-0.2379
	(0.6775)	(0.5523)	(0.2577)

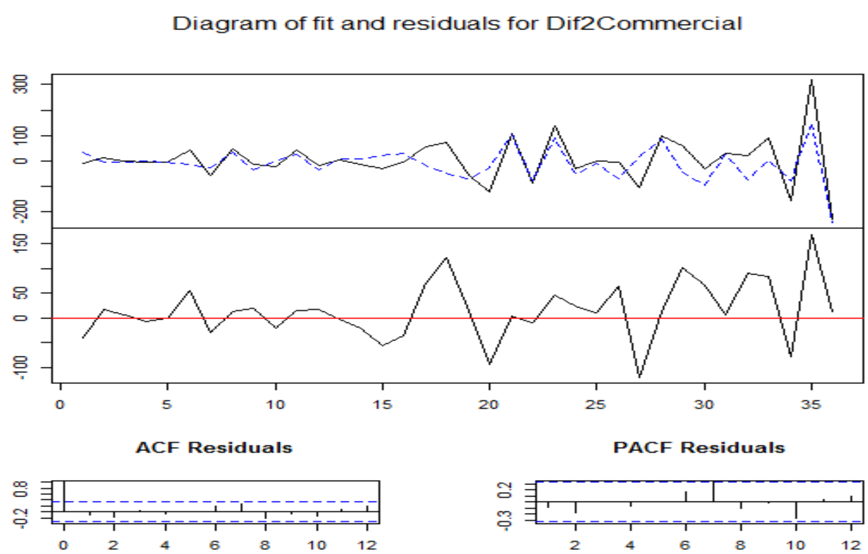
The asterisk (*) mark indicates that the corresponding coefficient is significant at 0.05 significance level. The significance of coefficients were tested with the null hypothesis that coefficient is zero against the alternative hypothesis that coefficient is not zero. According to the values of coefficients in Table 3, it is clear that series of second order differences of domestic demand depend only on its first and third lags. In case of demand of commercial sector, differenced series of demand of commercial sector is dependent on commercial sector at lag 1. Series of second order differences of demand in industrial sector depend on industrial sector at lag 1 and lag 2 and commercial sector at lag 3.

Demand for electricity depend on its' past demand as well as some other factors. Adom, Bekoe and Akoena [12] have identified factors affecting aggregate domestic electricity demand in Ghana based on data in the period from 1975 to 2005 by using ARDL bounds cointegration approach. It has been found that real per capita GDP, industry efficiency, structural changes in the economy, and degree of urbanization are the factors affecting long-rung demand while factors real per capita GDP, industry efficiency, and degree of urbanization affect demand in short-run.

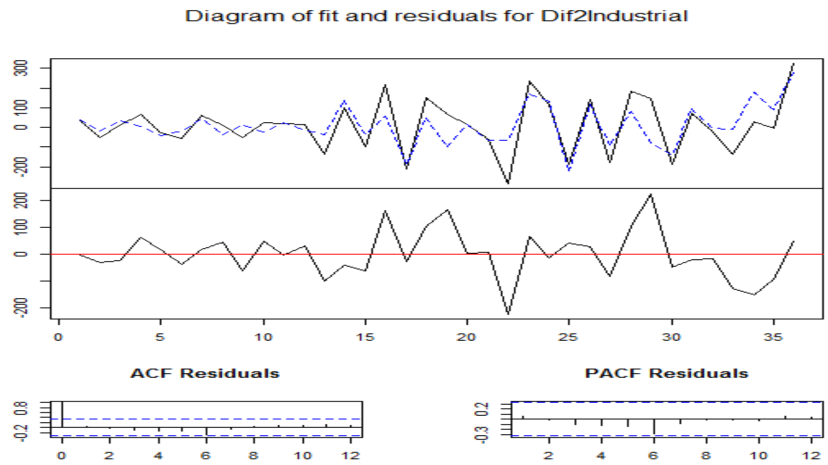
The JB-test confirmed the normality of residuals with a *P*-value of 0.06751. Assumption of constant variance of residuals was tested by using multivariate ARCH test. It confirmed the constant variance of residuals (*P*-value was 0.364). Portmanteau test and the Breusch-Godfrey LM (BG LM) test gave *P*-values of size 0.5653 and 0.09399 respectively. Both tests confirmed that residuals are not serially correlated at 0.05 significance level.



(a) Domestic



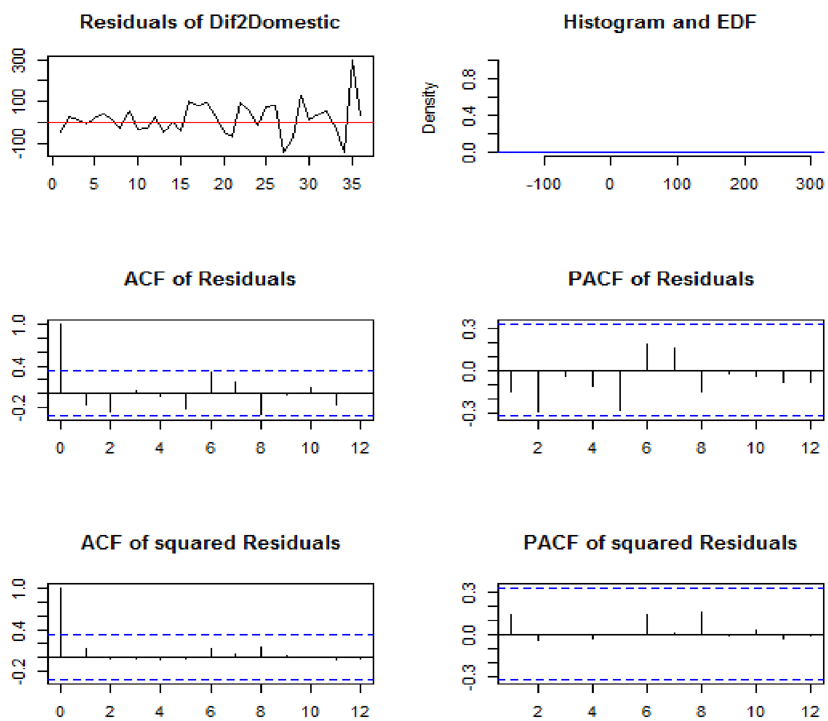
(b) Commercial



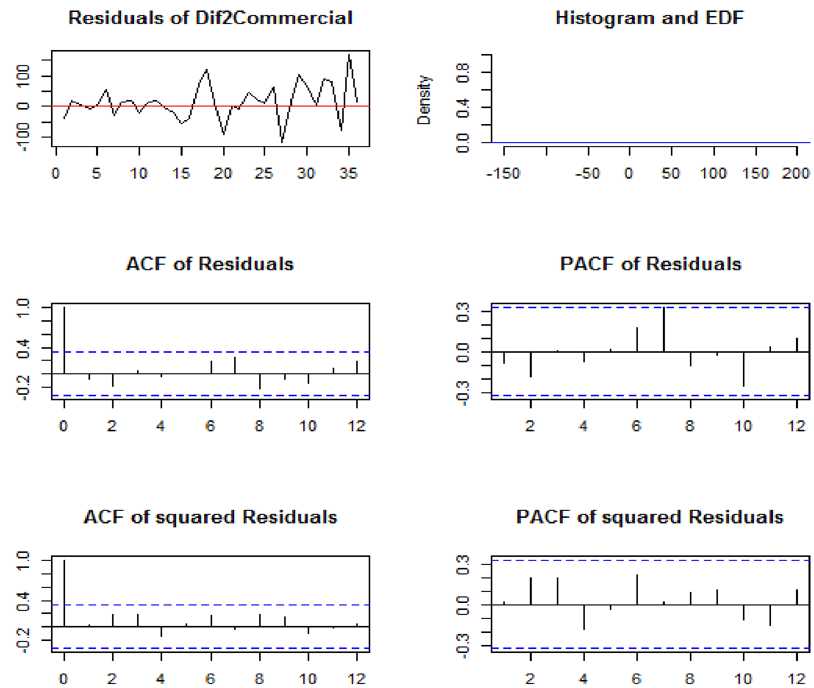
(c) Industrial

Fig. 2. Plot of fitted values and actual values with relevant ACF and PACF

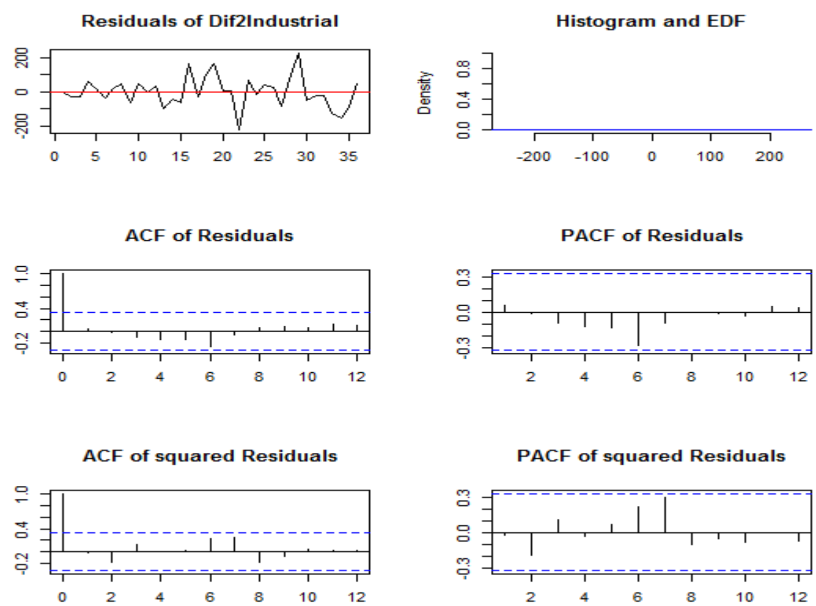
Fig. 2 above shows the actual values of series of second order differences and fitted values for them based on VAR(3) model. It can be seen that fitted values are closer to their actual values. This plot gives evidence for goodness of the fitted model.



(a) Domestic



(b) Commercial



(c) Industrial

Fig. 3. ACF and PACF of squared residuals of each series

It can be seen that forecasted demands are closer to their actual demand. Forecasting absolute errors are low in most of years. In 2013, forecasting error is higher for domestic and commercial sectors compared with other forecasting errors. These forecasting errors also confirmed the suitability of the fitted VAR(3) model.

The stability of the fitted model was tested with the ACF and PACF of squared residuals which are given in Fig. 3. All auto correlations and partial auto correlations are within the 95% confidence interval. It implies the stability of fitted model.

Forecasted demands for the period from 2011 to 2015 are given in Table 4 below with their absolute error percentages.

Table 4. Forecasted demand and error percentages

Year	Actual demand			Forecasted demand			Absolute forecasting error %		
	Dom.	Com.	Ind.	Dom.	Com.	Ind.	Dom.	Com.	Ind.
2011	3953	2495	3363	4030.21	2606.82	2829.57	1.95	4.48	15.86
2012	4115	2614	3522	3900.75	2535.93	3691.87	5.21	2.99	4.82
2013	4101	2737	3591	4761.04	3025.59	3393.28	16.09	10.54	5.51
2014	4112	2986	3750	4213.18	2812.34	4115.39	2.46	5.82	9.74
2015	4508	3178	3872	4666.55	3435.50	3313.22	3.52	8.10	14.43

4 Conclusions

There can be seen an increasing trend in demand for electricity in domestic, commercial and industrial sectors of Sri Lanka. But, degree of trend also has changed during the period considered. Up to around 1988, demands in domestic and commercial sectors were almost the same, while the demand in industrial sector was higher than that of the demand in other two sectors during the period up to 2000. After 1988, the demand in domestic sector was higher than the demand in commercial sector. During the period from 2000 to 2006, demands in domestic and industrial sectors were almost the same. But after 2006, demand in domestic sector has gone up than the demand in industrial sector. Model VAR (3) could explain the fluctuation in demand for electricity in Sri Lanka, with a minimum of 85% of accuracy in forecasting.

Competing Interests

Authors have declared that no competing interests exist.

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