American Journal of Energy Research, 2016, Vol. 4, No. 2, 35-41
Available online at http://pubs.sciepub.com/ajer/4/2/2

DOI:10.12691/ajer-4-2-2

Household Electricity Consumption of Middle Class Family in Chiitagong - A Case Study

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Abstract **Introduction:** Electricity is a necessity in the modern world. Electricity has attained a very important place in every household on this planet. It is a major contributor towards improvement of the standard of living of any individual, family and society at large. The aims of this study is to find out the monthly average household electricity consumption and fit a suitable time series model to predict the electricity use. **Data and Analysis:** A time series monthly electricity uses data of a middle class family in Chittagong from January 2001 to November 2015 is considered in this analysis. To check variability the descriptive statistics and different types of graphs are used. The volatility model ARCH family regression with ARIMA disturbances model is used for forecasting. Chow test statistic is used for checking the structural breaking point of the dataset. **Results & Conclusion:** From the ACF and PACF function we get the cut off point for AR and MA part are 2 and 3 respectively. Further as ARCH effect is significant for this data set we use ARCH family regression with ARMA disturbances model, After comparing the different value of the parameters, ARCH(1) with ARIMA (3,0,2) disturbances is best fit for this data set. There have a structural break point for the month of December in 2010. Before this date data, ARCH (1) regression family with ARIMA (2,0,2) disturbance is the best fitted model for the analysis. And for the post data follows only ARIMA(1,0,1) disturbance is the best fitted model for this analysis. **Recommendation:** For forecasting of the monthly electricity uses of a middle class family in Chittagong, ARCH(1) with ARIMA (3,0,2) disturbances time series model can be used. For better prediction one can consider to select a representative size of sample families with at least 20 years data. Also some covariates like family size and electronic items used in the family can be considered and can try to fit a GARCH or TGARCH model.

Keywords: *electricity consumption, ARIMA, ARCH, chittagong city corporation*

Cite This Article: Md Rokonuzzaman, Sharmin Jahan, and Md Shahidul Haque, "Household Electricity Consumption of Middle Class Family in Chiitagong - A Case Study." *American Journal of Energy Research*, vol. 4, no. 2 (2016): 35-41. doi: 10.12691/ajer-4-2-2.

1. Introduction

Electricity is a necessity in the modern world. Electricity has attained a very important place in every household on this planet. It is a major contributor towards improvement of the standard of living of any individual, family and society at large. This paper aims to find out the monthly average household electricity consumption and fit a suitable time series model to predict the electricity use.Adequate power supply enables better public health and economic growth. Developing nations face special challenges in planning the power grid infrastructure needed to support rapidly growing urban populations. About 80% of people in the world have access to electricity. This figure has increased in the last decade, mainly due to increasing urbanization.

Electricity is a flexible form of energy and critical resource for modern life and a vital infrastructural input for economic development. In all economies, households and companies have extensive demand for electricity. This demand is driven by such important factors as industrialization, extensive urbanization, population growth, rising standard of living and even the modernization of the agricultural sector. There is widespread discussion and research over the topic of relationship between electricity consumption and income particularly since early seventies of the last decades. Obviously, the degree of interest intensified since the Kraft and Kraft [10] findings. They found evidence of a uni-directional causal relationship running from GNP to energy consumption in the United States using data spanning from 1947 to 1974.

Electricity is a major source of energy in the industrial and agricultural sectors which are collectively contribute to 50.3 percent of Bangladesh's GDP. The contribution of agricultural and industry sector to GDP in fiscal year 2010-11 was 19.9 percent and 30.4 percent respectively (Bangladesh Bank, 2012). The share of agriculture and industry sectors in electricity consumption is increasing gradually. According to the Bangladesh Power Development Board (BPDB) statistics, about 45 percent (1995 to 2010) of total electricity was consumed by agriculture and industrial sectors. These statistics indicate that industry and agriculture together contribute significantly to GDP and electricity consumption as well. From this we can infer, therefore that electricity consumption plays an important role in economic growth of Bangladesh. It is, therefore important to identify the relationship between electricity consumption and national output and also their direction of causality to get a better understanding of the issues involved and determine the policy strategies.

Basically, a case study is an in depth study of a particular situation rather than a sweeping statistical survey. It is a method used to narrow down a very broad field of research into one easily researchable topic. The case study research design is also useful for testing whether scientific theories and models actually work in the real world. Though some argue that because a case study is such a narrow field that its results cannot be extrapolated to fit an entire system but, it is argued that a case study provides more realistic responses than a purely statistical survey. The other main thing to remember during case studies is their flexibility. Whilst a pure scientist is trying to prove or disprove a hypothesis, a case study might introduce new and unexpected results during its course, and lead to research taking new directions. The argument between case study and statistical method also appears to be one of scale. Whilst many 'physical' scientists avoid case studies, for psychology, anthropology and ecology they are an essential tool. It is important to ensure that you realize that a case study cannot be generalized to fit a whole population or ecosystem.

The advantage of the case study research design is that you can focus on specific and interesting cases. This may be an attempt to test a theory with a typical case or it can be a specific topic that is of interest. Research should be thorough and note taking should be meticulous and systematic.

In this study, the main purpose is made to examine the electricity consumption of a middle class family using monthly the time series data spanning from 2001 to 2015. Here we would like to relate the electricity consumption of a middle class family with econometric time series model such as ARIMA, ARCH models.

The second chapter of the study will present contextual information of the study where we discussed regarding current and future situation of Bangladesh's power sector. Section three is the literature review section, where we present relevant literature that will give us sound conception of the fact. The section four provides an avenue regarding research methodological approach and the relevant information on the time series data sets that are used for this study, while section five is discussed the empirical results. Finally, chapter six will provide the conclusion.

2. Literature Review

The study of the characteristics of economic dynamics and electricity sector has been an area of interest of researchers for long time. However, the pioneering work is investigating causal relationship between economic growth and energy consumption was done by Kraft and Kraft [10]. The existing literature focuses on developed and some developing economies. Different results have been found for different countries and different time periods. Those studies used different proxy variables for energy usage. This study will concentrate on the existing literature that is similar to our study. Ahmad and Islam [1] conducted a research on Bangladesh scenario. They found short-run unidirectional causality running from per capita electricity consumption to per capita GDP without feedback applying co-integration and VECM based Granger-causality test for the period spanning from 1971 to 2008. They also found long-run bidirectional causality running from per capita electricity consumption to per capita GDP. The findings of Asaduzzaman and Billah [5] also found positive relationship between energy consumption and economic growth for Bangladesh using data spanning from 1994– 2004 and reported that higher level of energy use led to higher level of growth. Buysse et. al. [7] investigated the possible existence of dynamic causality among electricity consumption, energy consumption, carbon emissions and economic growth in Bangladesh. The results indicate that uni-directional causality exists from energy consumption to economic growth both in short and long run, while bi-directional long run causality exists between electricity consumption and economic growth but no causal relationship exists in short run. Applying Granger causality tests on the nexus between economic growth and electricity generation, Alam and Sarker [3] claim that there exists a short run causal relationship running from electricity generation to economic growth without feedback. On the other hand, Mozumder and Marathe [14] found reverse relationship that is unidirectional causality from GDP to electricity consumption for Bangladesh over the period 1971 to 1999 by employing Co-integration and Vector Error Correction Model (VECM).

There are some notable studies conducted in the South Asian region. Ghosh [9] conducted a study using annual data covering the period of 1950–51 to 1996–97 in India and found that unidirectional Granger causality existed running from economic growth to electricity consumption. But, the same author in 2009 claimed that there was unidirectional causality running from economic growth to electricity consumption in the short run. The study conducted by Lean and Shahbaz [11] claim that electricity consumption has positive impact on economic growth and bi-directional Granger causality has been identified between electricity consumption and economic growth in Pakistan. However, Ahmad and Jamil [2] using annual data for the period of 1960–2008, found the presence of unidirectional causality from economic activity to electricity consumption. Morimoto and Hope [13] pointed out that current as well as past changes in electricity supply have a significant impact on a change in real GDP in Sri Lanka. Saeki and Hossain [15] found existence of unidirectional causality from economic growth to electricity consumption in India, Nepal and Pakistan, and from electricity consumption to economic growth in Bangladesh.

Asafu-Adjaye [6] investigated the existence of causal relationship between energy consumption and output in four Asian countries using the co-integration and error-correction mechanism and pointed out that unidirectional causality ran from energy consumption to output in India and Indonesia. However, bi-directional causality was found in case of Thailand and the Philippines. Akinlo [4] conducted a study in Nigeria to investigate relationship between economic growth and electricity consumption during the period 1980 to 2006. The result exhibits that there is unidirectional Granger causality running from electricity consumption to real GDP and suggested use of electricity could stimulate the Nigerian economy.

China, the largest developing country uses huge amount of energy. Recently, more attention has been given in China to determine the short run and long run causal relationship between electricity consumption and economic growth. However, conflicting result have been revealed by different researchers. Using yearly data covering the period 1978 to 2004 and applying co-integration and Granger causality approaches Yuan et. al. [17] indicated that electricity consumption and real GDP for China were co-integrated and there was unidirectional Granger causality from electricity consumption to real GDP. Shiu and Lam [16] claimed that causality existed running from electricity consumption to economic growth for the period 1971 to 2000. On the other hand, Lin [12] covered the 1978–2001 period and found that economic growth causes electricity consumption. Chontanawat et. al. [8] investigated the existence of causal relationship between energy economic growth nexus in 30 OECD developed economies and 78 non-OECD developing economies. They pointed out that causality running from energy consumption to GDP. However, the result was more prevalent in the developed OECD economies compare to the developing non-OECD economies. Employing autoregressive distributed lag (ARDL), the result indicated that there was positive relationship between electricity consumption and real GDP. The causality test confirms the uni-directional causal flow from electricity consumption to real GDP and the findings conclude that Malaysia is an energy-dependent country.

Thus the existing literature reveals that due to the application of different econometric methodologies and different sample sizes, the empirical results are very mixed and even vary for the same country and are not conclusive. That is why in this study, the main purpose is made to examine the electricity consumption of a middle class family using monthly the time series data spanning from 2001 to 2015.

Now data and methodology will be discussed.

3. Data and Methodology

This is a case study to examine the monthly electricity consumption of a middle class family in urban area of Chiitagong City Corporation. The monthly electricity bill is collected from a family produced by Power Development Board. The yearly income of selected family is approximately 3,00,000 BDT equivalent to $3900. According to BIDS, one belongs to the middle-class category when his/her family income per person income ranges between $2 and $3 per day.A time series analysis is employed for this dataset to forecast. Line diagram is produced to check the stationarity of the data. Also unit root test is used for stationary test. ACF and PACF is used for choosing the initial parameter of ARIMA. ANOVA table is used to test the equality of monthly average electricity uses and also to test the equality of year wise electricity uses. Loglikelihood, AIC or BIC is used to select the appropriate model. Eta squares is used for interpreting the proportion of the total variability in the dependent variable i.e accounted for by variation in the independent variable. STATA 12.0, SPSS 19.0 and MS Excel 2007 are used to analysis the data and to produce different types of graph.

4. Results and Discussion:

Line diagram of the monthly electricity consumption shows in Figure 1 and also Figure 2 shows month wise electricity consumption (in kWh) of the family. Usually in summer the electricity consumption is higher compare to other season and significant F-statistic (1.93) indicates the monthly unequal electricity consumption but it is obvious from the graph that there have no specific patterns of these line graphs. So we may say that in these data there have no seasonal variation and also the original data is almost stationary. Table 1 also shows the unit root test statistic for testing stationarity of the data set. Significant Augmented Dickey-Fuller test statistic implies that the data is stationary.

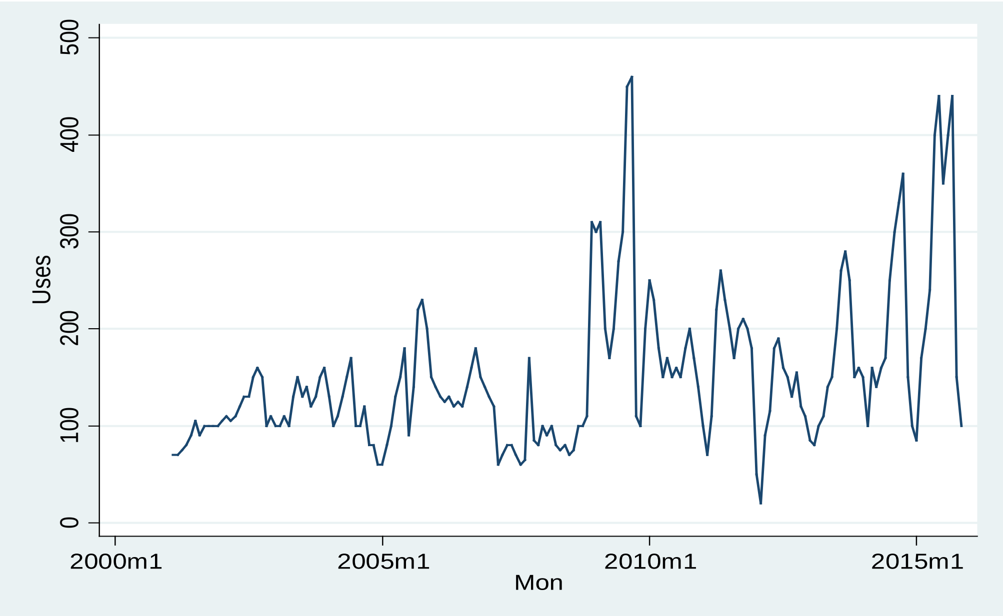

Figure 1. The line diagram of monthly electricity uses(in kWh) of a middle class family in Chittagong, Bangladesh

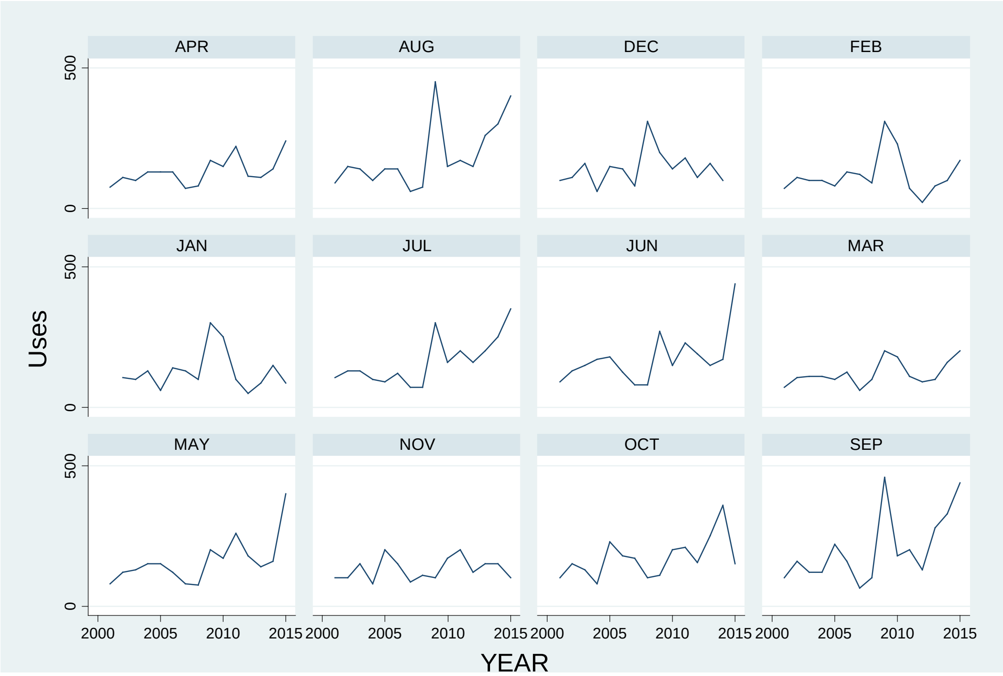

Figure 2. Month wise line diagram of average electricity uses(in kWh) of a middle class family in Chittagong, Bangladesh

Table 1. Unit Root Test for Stationarity

Augmented Dickey-Fuller test for unit root			Number of obs= 176			
			Z(t) has t-distribution			
	Test Statistic		1% Critical Value	5% Critical Value		10% Critical Value
Z(t)	-5.947		-2.348	-1.654		-1.286
p-value for Z(t) = 0.0000						
D.uses	Coef.	Std. Err.	t	P>|t|	[95% Conf.	Interval]
uses						
L1.	-.3055376	.0513793	-5.95	0.000	-.4069485	-.2041267
LD.	.2461426	.0736285	3.34	0.001	.1008169	.3914683
_cons	46.96554	8.794964	5.34	0.000	29.60629	64.32479

The monthly average electricity uses are shown in the Figure 3, implies that the highest electricity is used in the month of September with greater variability and lowest electricity is used in the month of February but the lowest variability is found for the month of November. The significant F statistic implies there have a statistical difference of monthly average electricity uses.

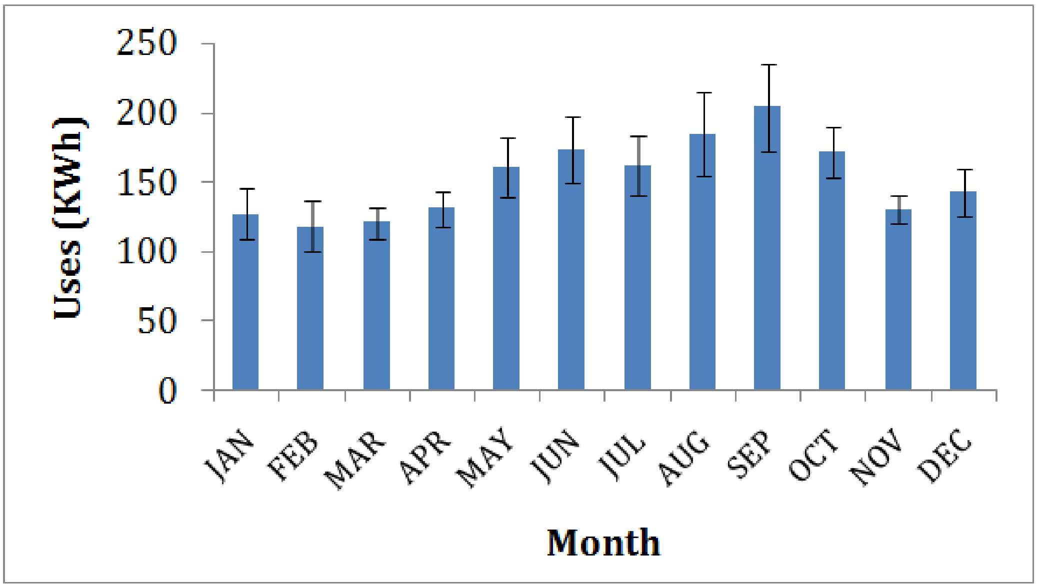

Figure 3. Monthly average electricity consumption with its standard error of the selected family

Figure 4 and Figure 5 represent the autocorrelation and partial autocorrelation graph, show the cuts off points are 3 and 2 respectively. Further the LM test statistic in Table 2 confirms ARCH(1). So we may choose ARCH(1) regression family with ARIMA(2,0,3) disturbance as an initial model.

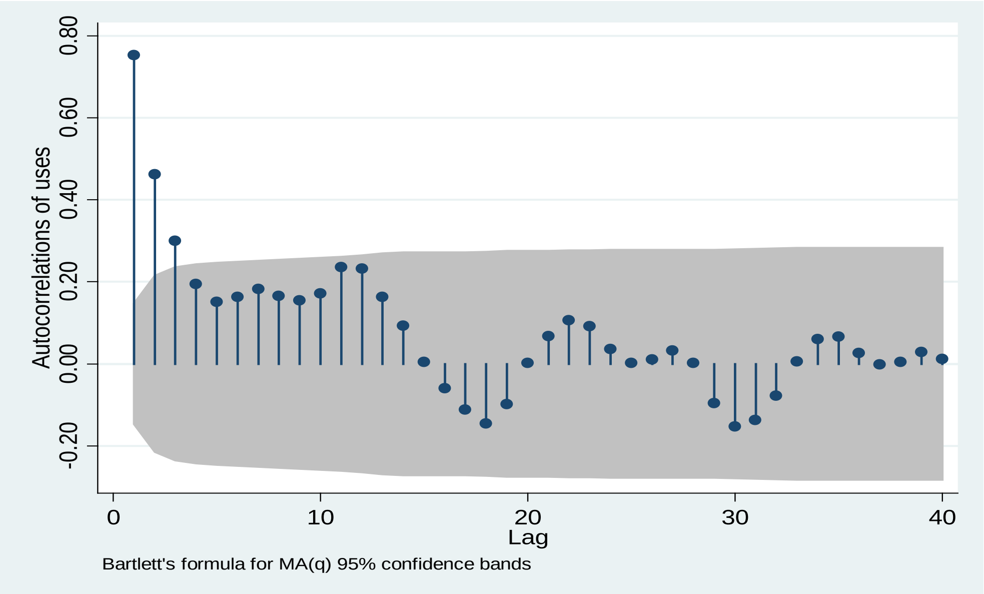

Figure 4. ACF curve for average monthly electricity consumption of the selected family

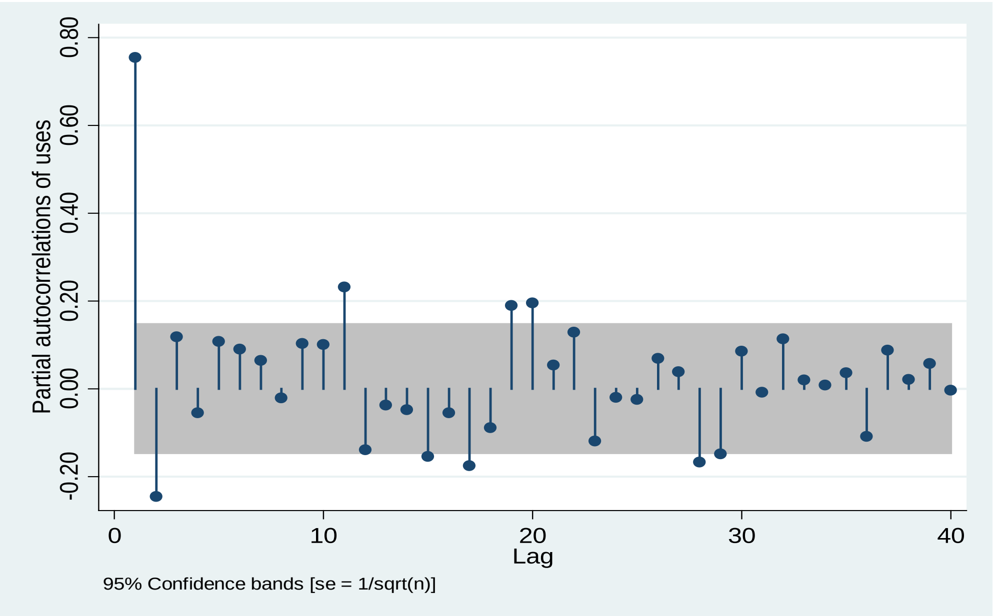

Figure 5. Yearly average electricity consumption with its standard error of the selected family

Table 2. LM test for autoregressive conditional heteroskedasticity (ARCH)

lags(p)	chi2	df	Prob > chi2
1	53.629	1	0.0000
H0: no ARCH effects	vs.		H1: ARCH(p) disturbance

For testing the ARCH effect, Table 2 conferred to use ARCH family regression. Further AIC or BIC is minimum for ARCH(1)regression with ARIMA(3,0,2)compared with ARIMA(2,0,1), ARIMA(2,0,2) and ARIMA(1,0,2) which are shown in Table 3.

Table 3. AIC, BIC and Wald Chi Square for Choosingappropriate Model

Model	AIC	BIC	Wald Chi Square	P Value
ARCH(1)regression with ARIMA(2,0,2) disturbances	1870.04	1892.31	9925.81	0.000
ARCH(1)regression with ARIMA(3,0,2) disturbances	1869.96	1890.41	9825.91	0.000
ARCH(1)regression with ARIMA(2,0,1) disturbances	1872.39	1891.48	150.28	0.000
ARCH(1)regression with ARIMA(1,0,2) disturbances	1872.35	1891.44	139.10	0.000

Table 4. Stata output of ARCH family regression with ARMA disturbances

ARCH family regression -- ARMA disturbances						
Sample: 2001m2 - 2015m11					Number of obs =	178
Distribution: Gaussian					Wald chi2(5) =	9825.78
Log likelihood = -927.9782					Prob > chi2 =	0.0000
uses	Coef.	Std. Err.	z	P>|z|	[95% Conf.	Interval]
uses						
_cons	109.5219	18.30324	5.98	0.000	73.64821	145.3956
ARMA						
ar			`			
L1.	2.332864	.1574734	14.81	0.000	2.024222	2.641506
L2.	-1.907321	.2770763	-6.88	0.000	-2.45038	-1.364261
L3.	.5846606	.1221612	4.79	0.000	.3452291	.8240921
ma						
L1.	-1.493939	.1637053	-9.13	0.000	-1.814796	-1.173083
L2.	.4749071	.1708198	2.78	0.005	.1401065	.8097077
ARCH						
arch						
L1.	.6533399	.1635878	3.99	0.000	.3327138	.9739661
_cons	1205.794	91.40628	13.19	0.000	1026.641	384.947

Final estimate of parameters of the statistical model ARIMA (3,0,2) with ARCH(1) for the data are shown in the Table 4. All the parameters are the statistically significant. The final regression model is

$$Y_t = 109.52 + 2.33Y_{t-1} - 1.91Y_{t-2} + 0.58Y_{t-3} - 1.49\varepsilon_{t-1} + 0.47\varepsilon_{t-2} + \varepsilon_t$$

with ARCH effect

$$\sigma_t^2 = 1205.79 + 0.65\varepsilon_{t-1}^2$$

where Y_t is the monthly electricity consumptions for the month t and ε_t is the residuals.

The predicted model is

$$\hat{Y}_t = 109.52 + 2.33\hat{Y}_{t-1} - 1.91\hat{Y}_{t-2} + 0.58\hat{Y}_{t-3} - 1.49\varepsilon_{t-1} + 0.47\varepsilon_{t-2}.$$

Line diagram and Chow test are used to check the structural break point. Line diagram seems to have structural break points at December 2010 and also the significant chow test statistic 5.66, indicates a structural break points in December 2010.

For the data with before December 2010, the estimated model ARIMA(2,0,2) with ARCH(1) is;

$$\hat{Y}_t = 98.28 - 0.31\hat{Y}_{t-1} + 0.77\hat{Y}_{t-2} + 1.24\varepsilon_{t-1} + 0.24\varepsilon_{t-2}$$

with ARCH effect

$$\sigma_t^2 = 244.49 + 1.69\varepsilon_{t-1}^2$$

where Y_t is the monthly electricity consumptions for the month t and ε_t is the residuals. All the parameters are statistically significant at 1% level.

For the data with after December 2010, the estimated model ARIMA (1, 0, 1) is;

$$\hat{Y}_t = 172.81 + 0.52\hat{Y}_{t-1} + 0.50\varepsilon_{t-1}$$

where Y_t is the monthly electricity consumptions for the month t and ε_t is the residuals. All the parameters are statistically significant at 1% level.

5. Conclusion

The aim of the study is to fit a suitable regression model for the monthly electricity consumption of a middle class family of Chittagong City Corporation Area, Chittagong, Bangladesh. The major findings are;

1. There have no specific pattern and there have no seasonal variation and also the original data is almost stationary.
2. The monthly average electricity uses are found highest for the month of September with greater variability and lowest electricity is used in the month of February but the lowest variability. There have an statistical significant difference of monthly average electricity uses.
3. The yearly average electricity uses are found highest for the month of September with greater variability and lowest electricity is used in the month of February but the lowest variability. There have an statistical significant difference of yearly average electricity uses.
4. The yearly average electricity uses are highest for the year 2015 with greater variability and lowest electricity with lowest variability is found for the year 2001. Also there have a slightly upward trend in yearly average electricity uses.
5. Unit root test conferred the stationarity of the data set. The autocorrelation and partial autocorrelation graph give us the cuts off points for MA and AR be are 3 and 2 respectively. Further the LM test statistic confirms to use ARCH(1) model.
6. Finally the ARCH(1) regression family with ARIMA(3,0,2) disturbance is the best fitted model for this analysis.
7. There have a structural break point for the month of December in 2010.
8. ARCH (1) regression family with ARIMA (2,0,2) disturbance is the best fitted model for the

analysis with the data up to December 2010. And for the data after December 2010 follows only ARIMA (1,0,1) disturbance is the best fitted model for this analysis.

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