Trend Analysis of Total Electric Energy Consumption of Households in Wolkite Town, Ethiopia

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Abstract
This study aims to identify the trend pattern of total electric energy consumption of households in Wolkite Town. To achieve this, the data considered in this study were monthly average total electric energy consumption recorded in (kilowatt/hour) of households from January 2014 to April 2020 in Wolkite town. The survey instrument was adapted from time series analysis method. The outputs of the analyses were done using Eviews 8 software.
Since, the supply of reliable electricity is prerequisite to development and prosperity, it should be measured on how behaves through time. In this regard, the finding of this study revealed that the amount of total electric energy consumption has significant increasing linear trend pattern over time (figure 1). The first difference of the series was found to be stationary. The model identified based on Box-Jenkins procedure was AR (1) with integrated of order one. Finally, this study is beneficial for the suppliers of the electric power and decision makers in order to stabilize the demand and supply of the electric energy consumption of households in the town.
Keywords: Electric Energy Consumption, Trend Analysis, Wolkite, Ethiopia.
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Background of the Study

Electric energy consumption is the form of energy consumption that uses electric energy. The share of world energy consumption for electricity generation by source was coal at 41%, natural gas at 22%, nuclear at 11%, hydro at 16%, other sources (solar, wind, geothermal, biomass, etc.) at 6% and oil at 4%. Coal and natural gas were the most used energy fuels for generating electricity. Total World final energy consumption includes products as lubricants, asphalt and petrochemicals which have chemical energy content but are not used as fuel (IEA. *September 2017).*

Today electricity is the leading cause of development and prosperity. Hence, every people and institution would use it in proper manner in order to avoid or minimize excessive power consumption. Despite of the abundant renewable energy resources, many communities still live without access to electricity either from the utility grid or independent renewable energy generated electricity. Supply of electricity to the population from grid system to each village is challenging due to their economic constraints. But electricity is a basic requirement to sustain water supply, communication, transportation, industrial, commercial and to a certain extent, agricultural activities. Thus, supply of reliable electricity is prerequisite to cater these services.

Nittaya Kerdprasop (1958) forecasts the electricity consumption in a household in Suranaree University of Technology, Thailand. The data analysis has been performed with the ARIMA (Autoregressive Integrated Moving Average) and ARMA (Autoregressive Moving Average) models. The suitable forecasting methods and the most suitable forecasting period were chosen by considering the smallest value of AIC and RMSE respectively. The result of the study showed that the ARIMA model was the best model for finding the most suitable forecasting period in monthly and quarterly. On the other hand, ARMA model was the best model for finding the most suitable forecasting period in daily and weekly.

The demand as well as the energy exploitation is rising in Ethiopia from single source mainly hydropower. Now a day's the government of Ethiopia has shown an interest towards other renewable energy sources. Thus, the abundant renewable resource available in nature can be harnessed and converted to electricity in a sustainable way to supply the necessary power demand and then to elevate the living standards of the people isolated from central grid.

The Ethiopian Government is now aware that the national utility alone through continuous grid extension cannot accelerate access to electricity. To improve access to electricity, the government has recently updated its strategies and improved any obstacle and constraints to accelerated off-grid electrification (Scaling up renewable energy). Among other off grid areas in Ethiopia, Wolkite town, a Gurage district administrative center, is the focus of this work.

Previous studies conducted in developing countries particularly in Ethiopia have documented that energy sources are substitutes to each other. However, studies on the trend characteristics for electric energy consumption and estimation of energy variation through time are very limited. The major goal of this study is to identify trend characteristics of the total electric energy consumption of households in Wolkite Town.

Methodology

Time series Stationarity is an important point to be described in time series analysis. A series is said to be stationary if the mean and autocovariances of the series do not depend on time. If both are constant over time, then the series is said to be a stationary process i.e. is not a random walk (has no unit root), otherwise, the series is described as being a non-stationary process i.e. a random walk or has unit root.

The opening stride in the analysis of time series is usually to plot the data and obtain simple descriptive measures of the main property of the series via a visual inspection of the time series plot. This may reveal one or more of the following characteristics: seasonality, trends either in the mean level or the variance of the series, long-term cycles, and so on. If any such patterns are present, then these are signs of non-Stationarity.

In this study, Augmented Dickey–Fuller (ADF) and Phillip–Perron (PP) tests are used to check the Stationarity of the monthly average total electric energy consumption of customers. Series that do not confirm to the assumption of Stationarity can often be transformed to a series into stationary time series values through the process of differencing.

To identify an ARIMA model for a particular time series data, Box and Jenkins (1976) proposed methodology that consists of four phases were applied: i) model identification ii) estimation of model parameters iii) diagnostic checking for the identified model and iv) application of the model (i.e. forecasting).

Results and Discussion

The data considered in this study were monthly average total electric energy consumption in (kilowatt/hour) of households observed from January 2014 to April 2020 in Wolkite town. The in-sample period spans from January 2014 up to December 2019 and the out of sample period spans from January 2020 through April 2020.

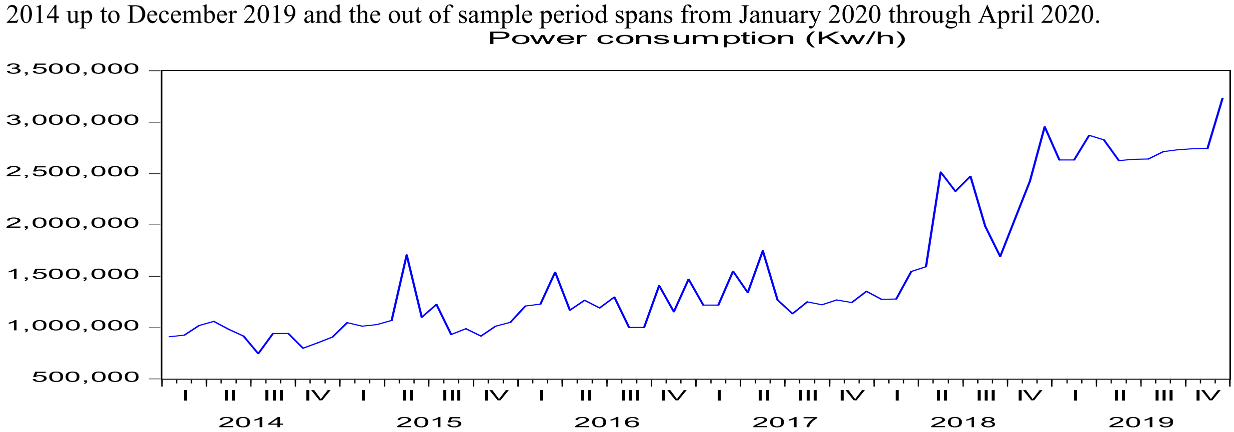

Figure 1.Trend of total Electric energy consumption from January 2014- December 2019 in Wolkite town

The dominance of the upward trend (figure 1) indicates that the average monthly total electric energy consumption of households continues rising over time. This implies that the mean may vary over time and the variance may also unstable for the average monthly total electric energy consumption of customers.

To select the most potential trend analysis from the above trend value, it is necessary to consider at least two measure of value for absolute mean percentage error (MAPE), mean absolute deviation (MAD) and mean squared deviation (MSD). So that the measure of MSD value for the linear trend is small and it should be selected for analysis (Table 1 Appendix).

The null hypothesis of the test of non-stationary (unit root) is rejected if the absolute value of the t-statistic is greater than the critical value or p-value is less than a given level of significance.

Table 2: ADF and PP Test for Electric Energy consumption and Electric Energy consumption (with first difference)

Variables	ADF Test		PP Test		Critical values		
	t–statistic	P-value	t–statistic	P-value	1%	5%	10%
Electric energy consumption(Yt)	-0.764	0.8294	-0.203	0.9382	-3.551	-2.913	-2.592
Electric energy consumption (first difference)	-11.056	0.000	-11.370	0.0000	-3.552	-2.914	-2.592

As Table 2 above, the null hypothesis of unit root would not be rejected for electric energy consumption of customers in both the ADF and PP tests at 1%, 5% and 10% level of significance. However, the first differences of the series were found to be stationary which is an indication that the series is integrated of order one (I $_{(1)}$).

It is seen in (Figure 1 Appendix) that the series has ACFs with exponentially decreasing pattern. That is, the sample ACFs has single significant positive peak at lag 1, 2, 3, 4, 5 and 6. On the other hand, the sample partial autocorrelation function (PACF) cuts off after lag 1 (Figure 2 Appendix). This may suggests that $AR(1)$ model with integrated of order one (I $_{(1)}$) is identified.

The presence of ARCH effect is tested using the squared standardized residuals from the selected $AR(1)$ model. Considering the chosen mean model, the squared Standardized residual plot can be an initial insight to judge the heteroskedastic characteristics of the disturbance term.

From the Ljung box test, the resulting p-values from the Ljung box test for residuals at different lags suggest that the ARCH effects are non- significant. Thus, the ARCH LM (Ljung- box test) test revealed that there is no ARCH effect in the residuals and GARCH family models are inappropriate to capture the volatility of the series (Table 3 Appendix).

The diagnostic analyses using the ACF of residuals and PACF residuals as shown in (Figure 4 and 5 Appendix) reveal that the residuals of the Model have zero mean and constant variance. The ACF of the residuals depicts that the Autocorrelation of the residuals are all zero. That is to say that they are uncorrelated. Imposing an invertibility condition ensures that there is a unique AR process for a given ACF. Hence, it can be concluded that there is a constant variance among residuals of the selected model and the true mean of the residuals are approximately equal to zero. Since all the p- values for Breusch-Godfrey LM test (Table 4 Appendix) are less than 0.05, so the residual is independent and uncorrelated. The figure shows that most of the residuals are not much far from the line showing randomness so; this implies that the fitted model is appropriate for the data.

Finally, the forecasting accuracy of the fitted model from January 2020 _April 2020 was employed. The in-sample predictions were plotted on left side of the vertical line (this dataset has a time index that runs from December 2014 to December 2019 for dash line) while the right side of vertical line forecasts were out-of-sample (Figure 8 Appendix).

Conclusions

The main objective of this study was focused on fitting an appropriate trend characteristics for total electric energy observed from January 2014 to December 2019 in Wolkite town. In this regard, the finding of this study showed that the amount of total electric energy consumption has significant increasing trend pattern over time (figure 1). Unit root tests indicate that all indices are non-stationary at level and the first difference of the series was found to be stationary at 1%, 5% and 10% level of significance. The suitable time series model was chosen by considering the smallest value of AIC and BIC respectively. Finally, the study revealed that AR (1) model with integrated of order one (I $_{(1)}$) is found to be appropriate for estimating model parameters and forecasting compared to the other models in the context of setting this study. Error diagnosis of this model showed that the disturbance terms are white noise and approximately normally distributed. Eventually, this study is beneficial for the suppliers of the electric power and decision makers in order to stabilize the demand and supply of the electric energy consumption of households in the town.

Appendix

Table 1: Accuracy measures of linear trend and quadratic trend for the series

Accuracy Measures	Linear trend	Quadratic trend
MAPE	$2.03304E^{+01}$	$1.33882E^{+01}$
MAD	$2.00018E^{+05}$	$2.00018E^{+05}$
MSD	$1.23224E^{+10}$	$6.58640E^{+10}$
Fitted equation	Yt = 524757 + 28249.1*t	Yt = 1083086 - 17020.8*t + 620.136*t**2

Table 2: Final Estimates of model Parameters

Model coefficients	Coef. Value	Std. error	Test statistic	p-value	[95% Conf. Interval]
Constant	1742352	540312.3	3.22	0.170	(-683359.3, 2801345)
Coefficient	0.9528629	0.0554568	17.18	0.000	(0.8441696, 1.061556)

Table 3: LM test for autoregressive conditional heteroskedasticity (ARCH)

lags(p)	chi2	df	Prob > chi2
1	0.856	1	0.3548
2	0.820	2	0.6636
3	1.655	3	0.6471
4	1.835	4	0.7662
5	1.852	5	0.8692
6	2.637	6	0.8528
7	2.985	7	0.8864
8	3.536	8	0.8964
9	4.412	9	0.8823
10	4.954	10	0.8942
11	5.262	11	0.9178
12	5.493	12	0.9395

Table 4: Breusch-Godfrey LM test for autocorrelation

Lag	1	2	3	4	5	6
Ch-Square	16.493	16.823	18.379	18.931	22.333	22.496
DF	1	2	3	4	5	6
p - value	0.0573	0.0784	0.0732	0.0926	0.1253	0.0720

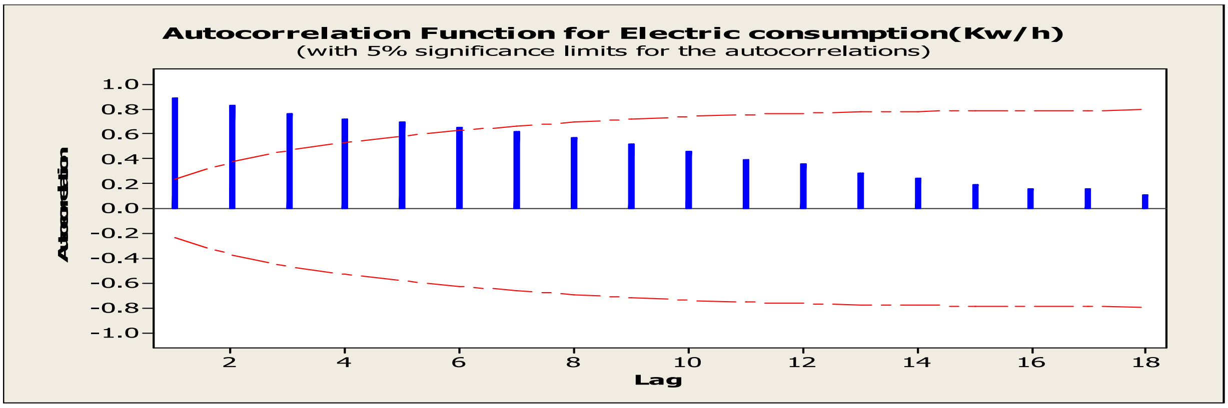

Figure 1. Autocorrelation of Total Electric Energy consumption

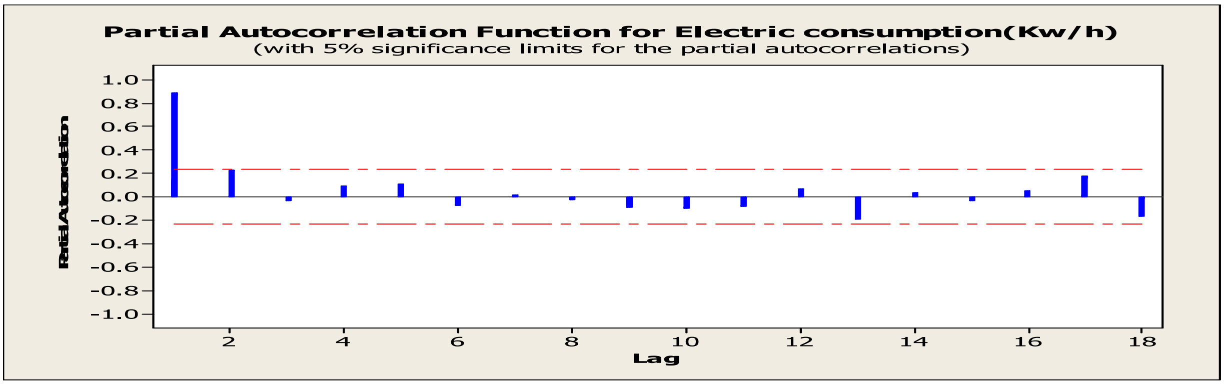

Figure 2. Partial autocorrelation of Total Electric Energy consumption

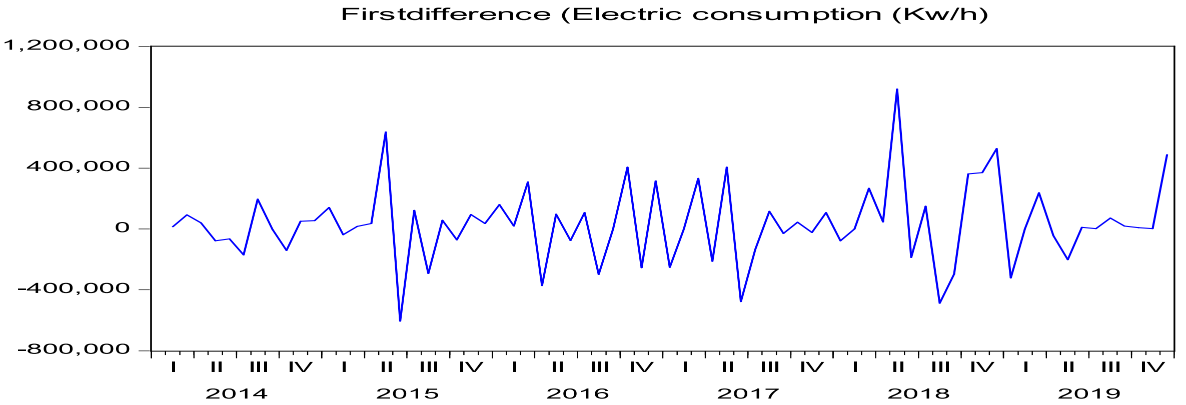

Figure 3. Time series plot after differencing data of electric total electric energy consumption

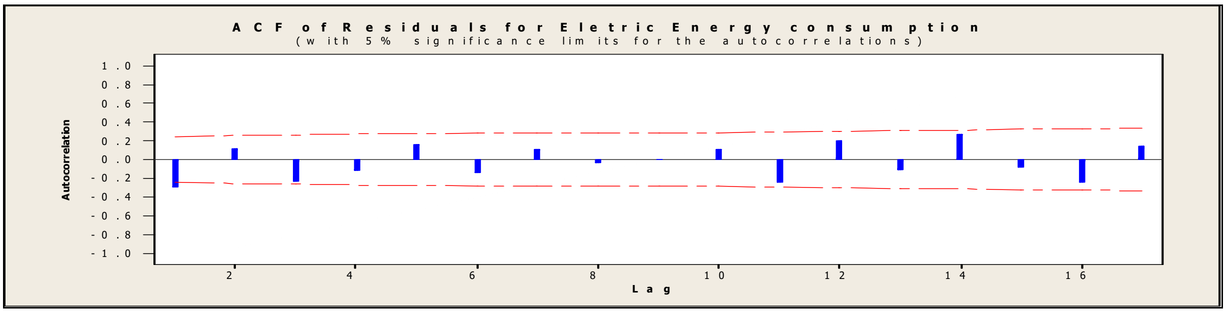

Figure 4. Autocorrelation for electric energy consumption

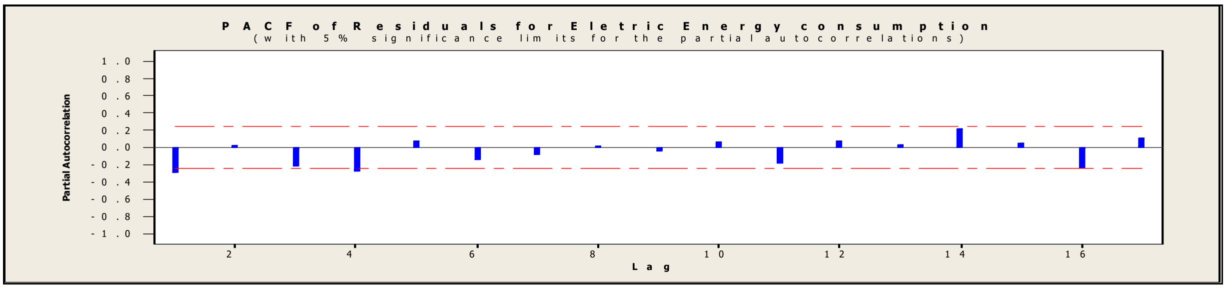

Figure 5. Partial autocorrelation for Electric energy consumption

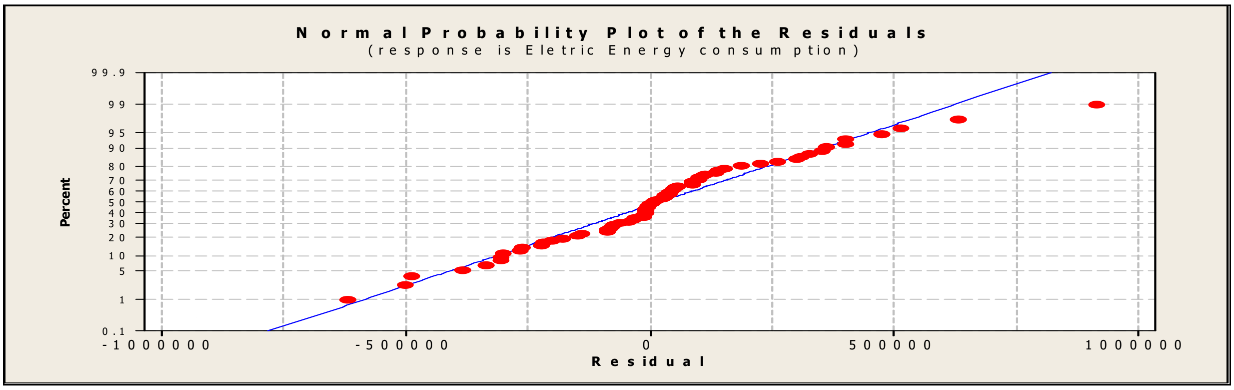

Figure 6. Normal Probability Plot (p-p) of the Residuals for AR (1)

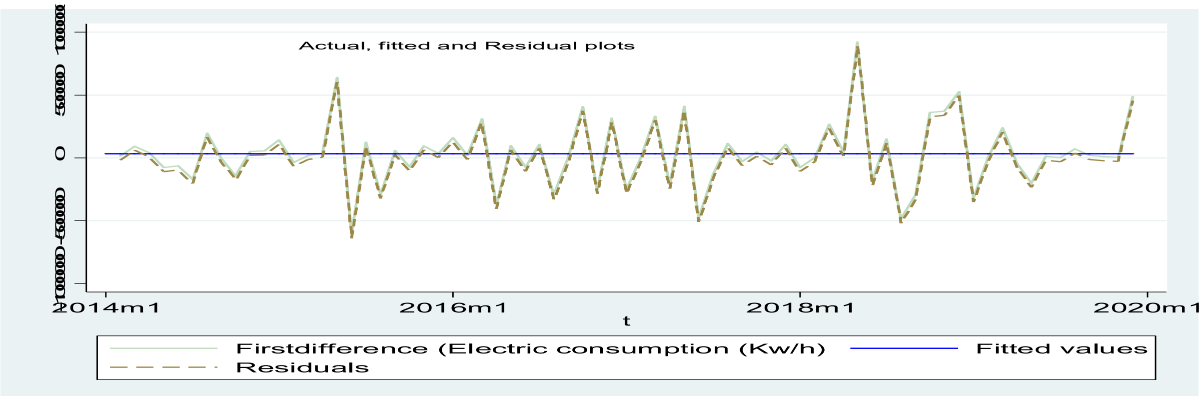

Figure 7. Graph of Actual, Fitted and Residual plots of Electric consumption (with first difference)

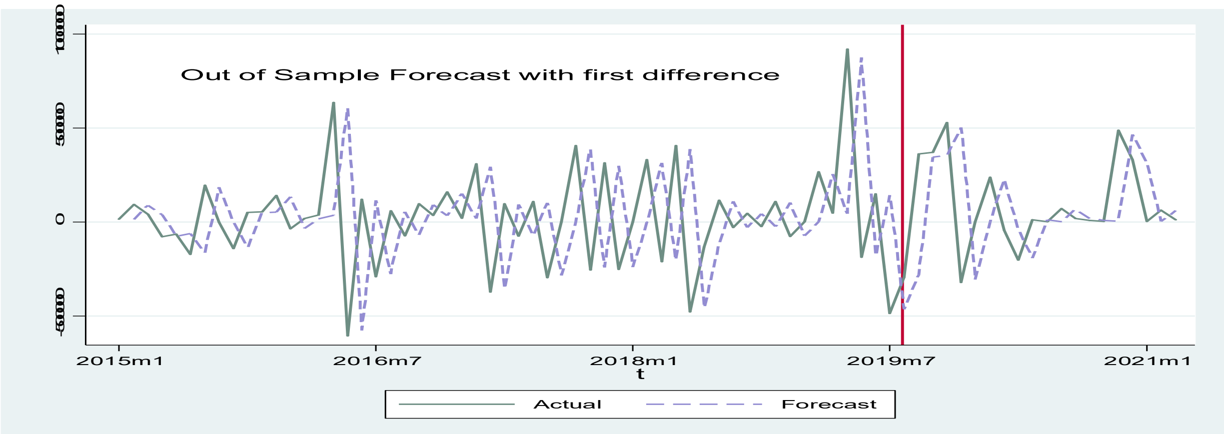

Figure 8. In-sample prediction and Out- of sample Forecast

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